A WINDOW OPEN ON THE WORLD

SPECIAL NUMBER

The UNESCO Courier

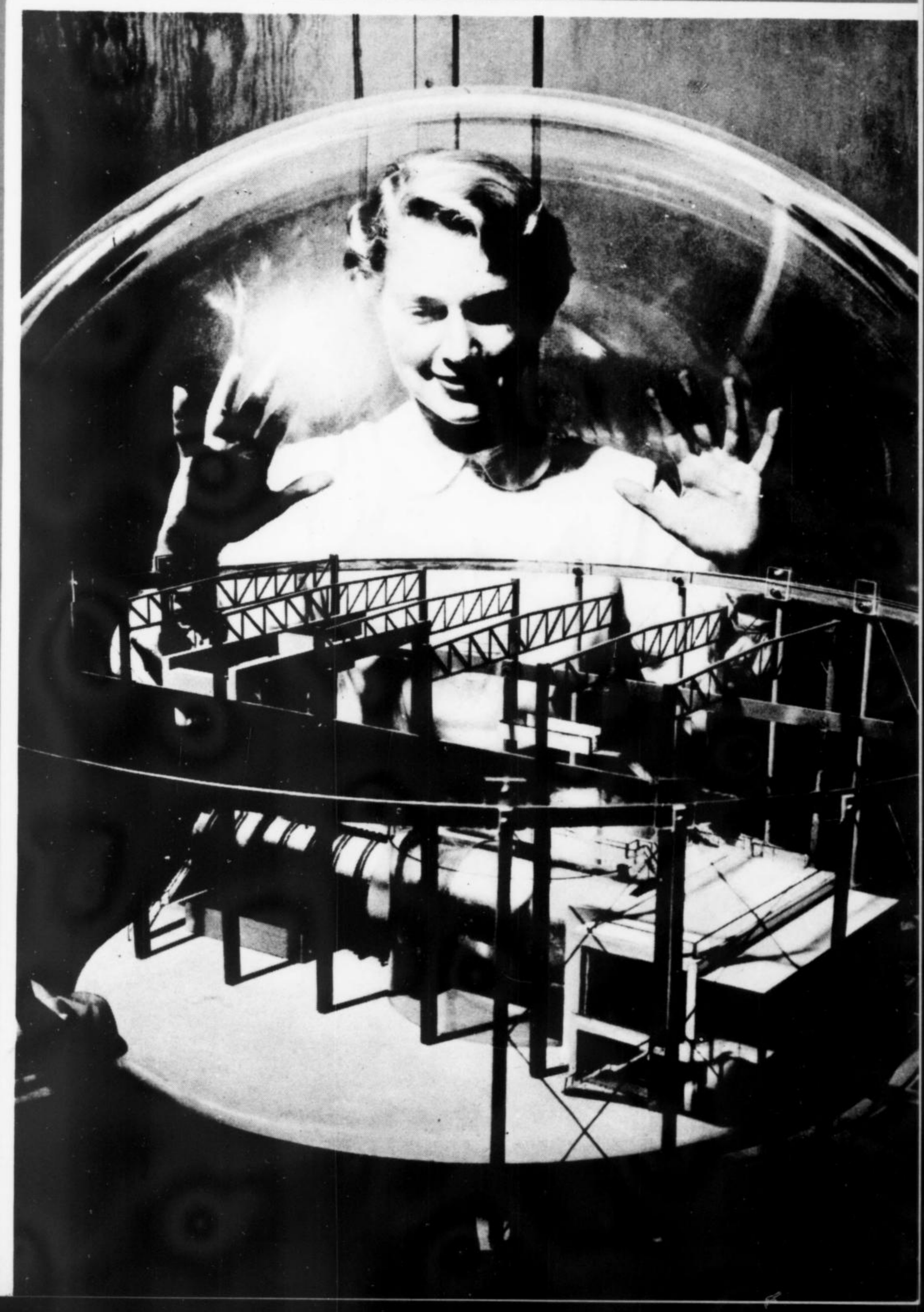
UNITED NATIONS EDUCATIONAL SCIENTIFIC AND CULTURAL ORGANIZATION

MARCH
1955
Price 25 cents

ATOMIC POWER

THE HOPES
THE REALITIES

A WORLD PICTURE
FROM THE U. S. A.
TO THE U. S. S. R.



INSIDE THE ATOMIC FURNACE: First photograph taken of the inner part of an atomic reactor in operation. Here, a chain reaction begins with uranium or other fissionable material producing the great heat which can be used for the generation of power. This "Swimming Pool" reactor, at Oak Ridge, U.S.A., is built in a 130,000 gallon tank of water to keep its radiation from escaping. (Photo USIS).

The UNESCO Courier

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THE COVER: Looking into the future at a scale model of an atomic power plant. Scientists consider that the world's tremendous need for increased power can be met by such plants, using atomic fuel converted from the world's reserve of uranium. This reserve is many times the energy equivalent of the world reserve of coal and oil. *(Photo USIS).*

THE PROMISE OF ATOMIC POWER

For almost ten years the atom has shown an evil face. Before the General Assembly of the United Nations in November, it began to show a happier one.

By one of the tragic accidents of history, the discovery that enormous energy is released when a uranium atom is split by a neutron came in 1939, just before the outbreak of the greatest war in history. It was at once used to create the horrendous succession of bombs which ended that war and have now made another war almost unthinkable. But it is the bomb that brings death and destruction, not the atom. In better times and in wiser hands the energy of the atom can do far more good than the harm the bomb has done. Today there is great hope that a better time is at hand and that the atom will become a benefactor of humanity.

The use of atomic energy to do the world's work has long been the dream of scientists. The measure of man's progress in civilization has been his increased use of energy. But we still have far to go. A new source of energy that can be used at any place on earth would benefit the non-industrialized nations at once and would enable them to develop now the coal-free and oil-free economy that all nations must sooner or later adopt.

This is the promise of atomic energy. One pound of uranium fuel can provide as much energy as 1,300 tons of coal, yet the coal weighs nearly three million times as much. Furthermore, atomic fuels have precious by-products in the radio-active materials, called isotopes, that are produced in the atomic furnaces. They will almost certainly benefit mankind as much as will the use of atomic energy itself.

Knowing all these possibilities, scientists the world over have been dismayed at the restriction of atomic materials to military use. They expected to avoid further development of atomic weapons and to stimulate the peaceful uses of atomic energy for all the world. Nationalism and international tensions made this impossible.

But a new start now has been made. A proposal was made by President Eisenhower to the United Nations General Assembly on December 8, 1953, for international co-operation in the peaceful development of atomic energy and atomic materials. Suddenly the great hopes of long ago were revived by the unanimous adoption of this proposal by the Political and Security Committee of the General Assembly on November 23, 1954, and by the General Assembly itself, also unanimously, on December 4. This makes certain one great advance : international co-operation in atomic development under the United Nations. It makes possible another equally great : the full use of the atom for the good of mankind.

This may be a turning point in history. The prospect needs careful study. It is not a problem for scientists and statesmen alone. In a democratic world an understanding of the atom and its possibilities is necessary for every literate and thinking person. It will no doubt be quickly introduced into the schools. But it must also be introduced into public discussions.

The UNESCO COURIER, as Unesco's medium of public information and education, devoted its December issue a year ago largely to an exposition of the fundamental sciences of atomic energy. Now, with the assurance of international action by the United Nations and by Unesco toward the practical use of atomic power and atomic materials, this entire issue is devoted to a realistic examination of the facts, the possibilities, and the prospective consequences of the beneficent atom.

A TURNING POINT

By Gerald Wendt

THE unanimous vote of the General Assembly of the United Nations on December 4, 1954, for the setting up of an international atomic energy agency and for a United Nations conference on the peaceful uses of atomic energy was hailed in countries all around the world.

The problem of making the full use of the atom for the good of mankind is not one for scientists and statesmen alone. Every thinking and literate person should have an understanding of the atom and its possibilities. Men and women everywhere should understand the implications of the U.N. decision, and they should welcome it with enthusiasm. The reasons, plain to see, are these:

1. After the years of fixation on weapons and on the chill fear of destruction, the dark skies broke and a beam of sunshine brought hope, if not a promise, of better times to come. The evil spell of the atom was cast off by honest plans for peace and benefits to humanity from the great new resource that science had created. It brought a relief from war talk, if not an end to it.

2. It was a unanimous vote for a unanimous benefit. It meant that all the member states would profit together, large and small, east and west, industrial and agricultural, rich and poor. And it meant that the United Nations is a force in being which can seize upon a great vision and can act to give it reality. For once it was not merely a nation or a power-group but the whole organized world that agreed to co-operate in exploring a new road to human welfare.

3. It is a road that will eventually lead to a large increase in useful energy, in power to do the world's work. And energy creates material wealth and replaces hard human labour by leisure and well-being.

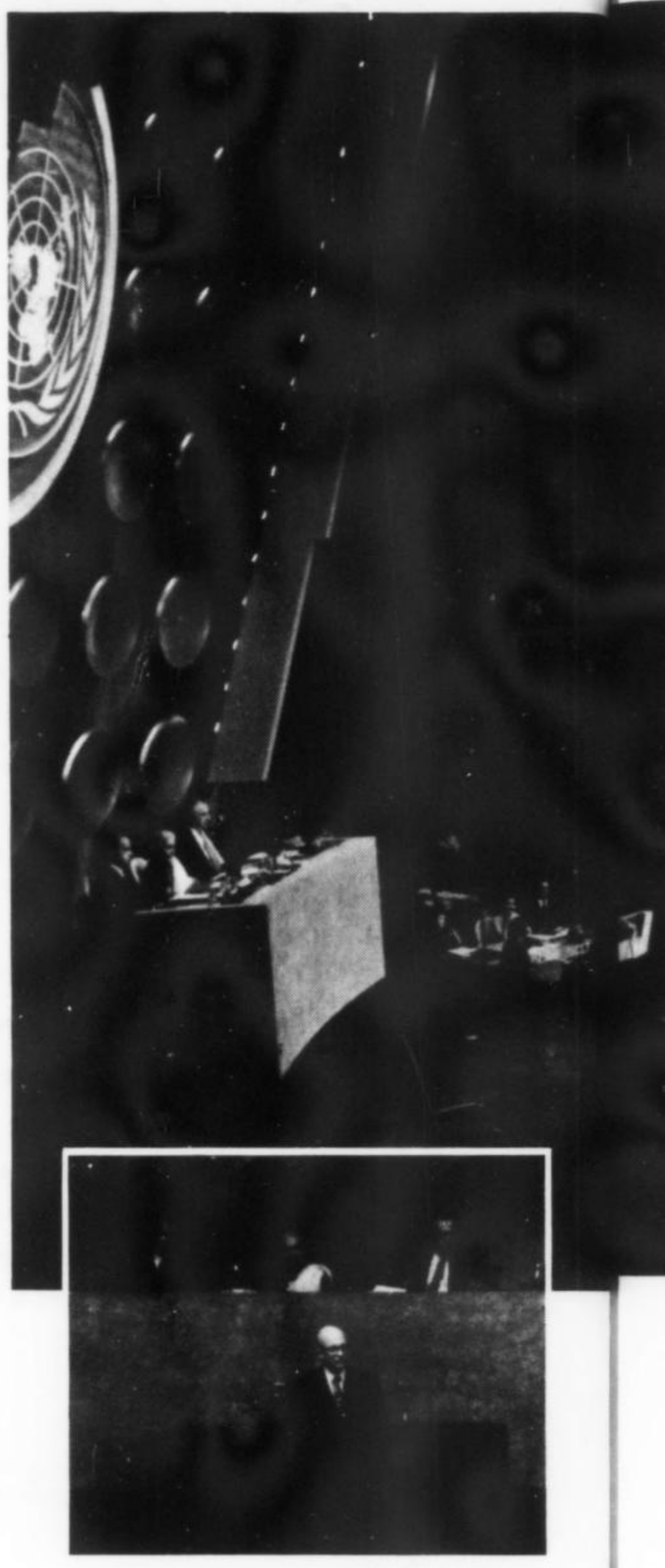
4. Just as surely, the by-products of the atomic furnaces, the radio-isotopes, are instruments for the exploration of nature as powerful as were the microscope and the telescope in their early days. Especially in the revelation of the deep secrets of the life processes, they will bring a new era in science and therefore in human living.

5. In order to achieve these benefits in the nations that are not now active in the study and production of atomic energy, a major increase in educational facilities will be needed. They must be provided in advance. The production of atomic energy on a large scale demands not only highly specialized nuclear physicists and chemists but also thousands of engineers. electrical, civil and mechanical, and many more skilled workmen to operate and maintain the reactors, the electrical generators, the entire electrical distribution system and the myriad motors and electrical machines that will use the energy. Furthermore, in order to use radio-isotopes as a research tool, there will need to be scientific laboratories, especially in the biological and medical sciences, and training schools for the use of the new techniques in nearly all the research sciences and in industrial research. Indeed, in order to provide training at these levels, the nations who expect to participate will need a broad programme of improved secondary education, including the provision of modern laboratories and teaching methods in the secondary schools. If the atomic energy programme serves as an incentive to stimulate such programmes of scientific education in the countries that do not now have them, this in itself will constitute a benefit, quite apart from the direct benefits from the use of atomic energy.

6. Finally, the availability of ample energy, especially in lands where power has been scarce and industry therefore weak, will bring a social revolution comparable with the industrial revolution of a century and a half ago. The advances in agriculture, nutrition, medicine and health will alone cause rapid social changes, even in the industrial countries. The world has in the past let such revolutions develop unforeseen, often with disastrous consequences as well as benefits. This time we can see it coming. This time many a people will leap from the age of bullock-power to the atomic age. If the prospect is breathtaking, it is also an inspiring challenge to the educators, social scientists, national planners and governments.

It is because benefits from the international development of atomic energy are so incalculable and because the pace at which these changes will proceed are dependent on so many factors that the whole international atomic project deserves study not only by the international conference that will be called by the United Nations in 1955, but by the informed public in every country. Much depends on the demand for energy in various countries, on the cost of atomic power, on the location of atomic reactors, and on the ability of each country to utilize the additional energy and the new knowledge. That is why the reasons given above for welcoming the U.N. decision are considered in the subsequent articles of this series.

For a biographical note on Dr. Wendt, the author of the articles in this issue, see page 50.



Let's use the atom for the good of mankind

HISTORIC PROPOSAL for international co-operation in the peaceful development of atomic energy and atomic materials was made by President Eisenhower to the United Nations General Assembly, on December 8, 1953. (Photos, above and inset, show President Eisenhower addressing the General Assembly. Seated behind him are, left to right: Mr. Dag Hammarskjöld, Secretary-General of the United Nations; Madame Vijaya Lakshmi Pandit, of India, President of the General Assembly at that time; and Mr. Andrew W. Cordier, Executive Assistant to the Secretary-General. Just under a year later, on December 4, 1954, the General Assembly unanimously voted for the establishment of an international atomic energy agency and for a United Nations conference on the peaceful uses of atomic energy. (U.N. photos)

DURING the years since the end of World War II in 1945, the power of the atom seemed too great for human wisdom. Developed under military necessity and regarded in a time of tension as the supreme weapon, it forced its sponsors into rivalry and secrecy. Persistent efforts to abolish its military use failed for lack of mutual trust between the nations involved. Instead, its power grew under the fierce competition and multiplied a thousandfold until, if it were now used in war, the entire human race would suffer and perhaps perish. Meanwhile, any wide use of that great power for the peaceful work of the world has been impossible because relaxation of secrecy also requires international control based on mutual trust. So the world stood still while the evil grew.

Door to the future

THEN, on December 8, 1953, the President of the United States addressed the General Assembly of the United Nations and opened a new door to the future. He said in part:

"The United States knows that if the fearful trend of atomic military build-up can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind. The United States knows that peaceful power from atomic energy is no dream of the future. That capability, already proved, is here—now—today. Who can doubt, if the entire body of the world's scientists and engineers had adequate amounts of fissionable material with which to test and develop their ideas, that this capability would rapidly be transformed into universal, efficient, and economic usage?

"To hasten the day when fear of the atom will begin to disappear from the minds of the peoples and the governments of the East and West, there are certain steps that can be taken now.

"I therefore make the following proposal:

"The governments principally involved, to the extent permitted by elementary prudence, to begin now and continue to make joint contributions from their stockpiles of normal uranium and fissionable materials to an international atomic energy agency. We would expect that such an agency would be set up under the aegis of the United Nations...

"Undoubtedly, initial and early contributions to this plan would be small in quantity. However, the proposal has the great virtue that it can be undertaken without irritations and mutual suspicions incident to any attempt to set up a completely acceptable system of world-wide inspection and control."

Protecting the 'bank'

"THE atomic energy agency", said the President, "could be made responsible for impounding, storage, and protection of the contributed fissionable and other materials. The ingenuity of our scientists will provide special safe conditions under which such a bank of fissionable material could be made essentially immune to surprise seizure.

"The more important responsibility of this atomic energy agency would be to devise methods whereby this fissionable material would be allowed to serve the peaceful pursuits of mankind.

"Experts would be mobilized to apply atomic energy to the needs of agriculture, medicine, and other peaceful activities. A special purpose would be to provide abundant electrical energy

(Cont'd on next page)

Pooling atomic knowledge (Cont'd)

in the power-starved areas of the world. Thus the contributing powers would be dedicating some of their strength to serve the needs rather than the fears of the world.

"The United States would be more than willing—it would be proud—to take up with others principally involved the development of plans whereby such peaceful use of atomic energy would be expedited.

"Of those 'principally involved' the Soviet Union must, of course, be one.

"I would be prepared to submit to the U.S. Congress, and with every expectation of approval, any such plan that would:

First. — Encourage world-wide investigation into the most effective peace-time uses of fissionable material.

Second. — Begin to diminish the potential destructive power of the world's stockpiles.

Third. — Allow all peoples of all nations to see that, in this enlightened age, the great powers of the earth, both of the East and of the West, are interested in human aspirations, first and foremost, rather than in building up the armaments of war.

Fourth. — Open up a new channel for peaceful discussion and initiate at least a new approach to the many difficult problems that must be solved in both private and public conferences if the world is to shake off the inertia imposed by fear and make positive progress toward peace.

"Against the dark background of the atomic bomb, the United States does not wish merely to present strength, but also the desire and hope for peace."

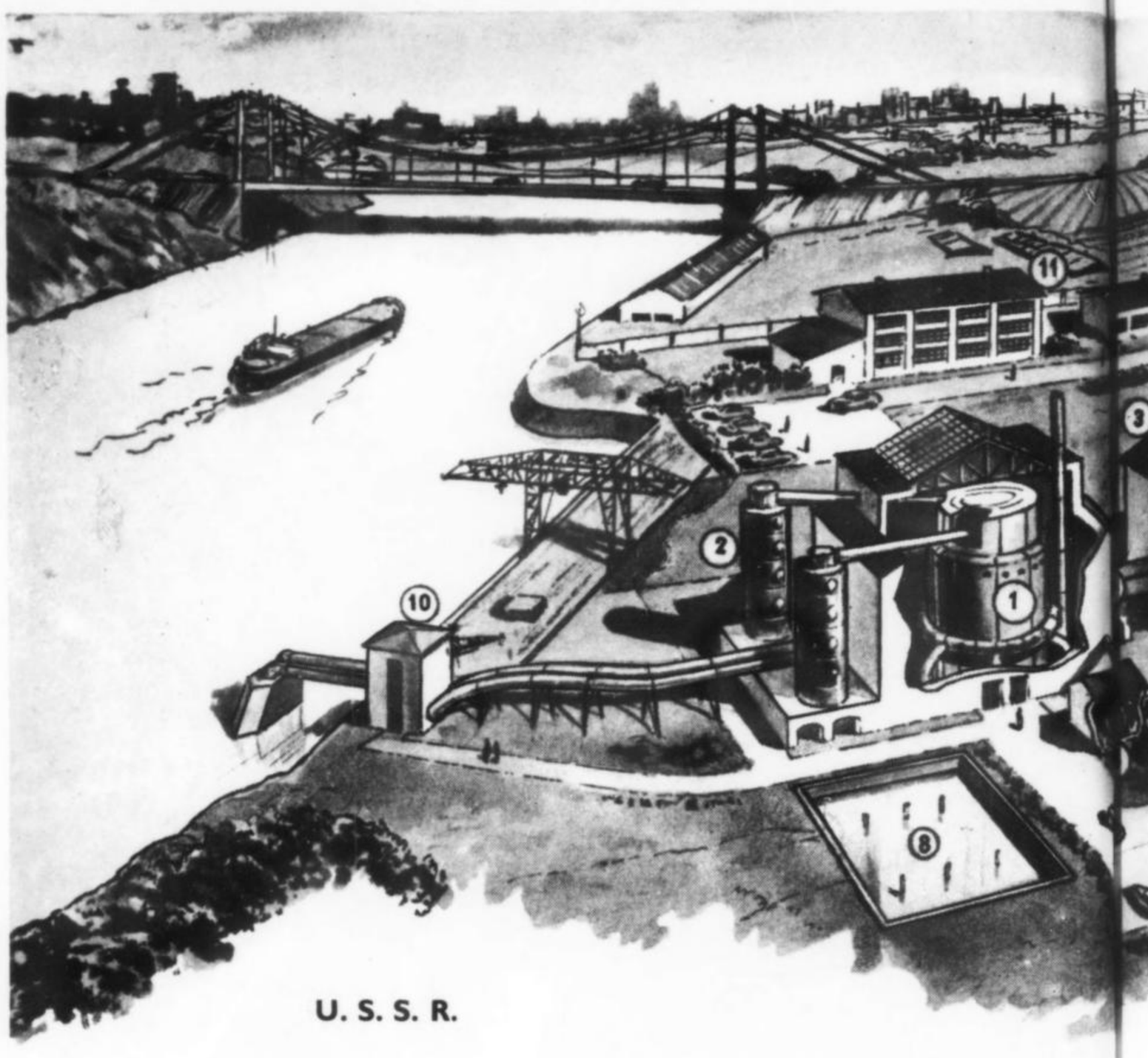
A fearful dilemma

THIS effort to help solve the fearful atomic dilemma at once inspired new hope in the hearts of many nations. In the British House of Commons, Sir Winston Churchill said that he considered the speech as one of the most important events in world history since the war and referred to it as possibly "a turning point in our destiny". The speech was, however, but a first step and not a complete solution. Indeed, the Soviet delegate, the late Andrei Y. Vishinsky, soon pointed out that it did not mention banning of atomic weapons, would involve only a small part of the existing atomic materials, and, in effect, merely transferred the discussion to a new aspect of the problem. But in most nations this was nevertheless considered a major step in advance. Mrs. Vijaya Lakshmi Pandit of India, then President of the United Nations General Assembly, stated that "the proposal was of the highest importance and deserves the careful consideration of all the governments of the world. It is something my country welcomes."

Months of careful consideration by governments, scientists and leaders of thought raised no doubts as to the value of atomic energy in the peaceful ways of life. The questions related only to the other and deeper purpose of the proposal: the extent of international co-operation. Did it mean an international "pool" of atomic materials? If so, which nations would contribute and which receive? Did it mean that an international staff in an agency of the United Nations would be in charge of operations and research? If so, from which nations would they come and how would their expert secret knowledge be safeguarded? Above all, did the proposal imply any reduction of atomic armaments?

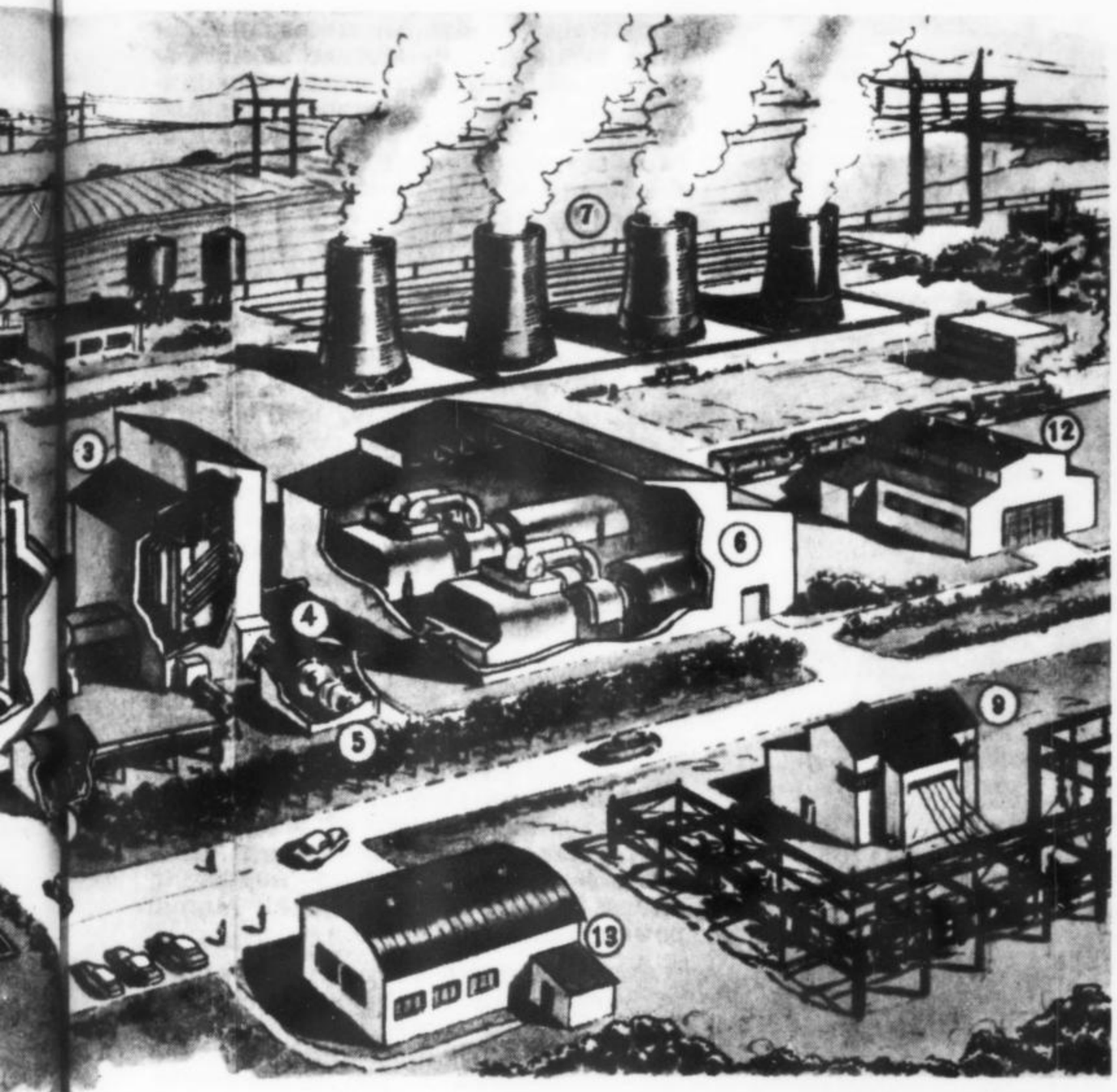
This last point was the major question raised by the Soviet Government on December 21, 1953, in stating that its attitude was: "to turn this great discovery of the human mind not against civilization, but for its thorough progress; not for mass extermination of people, but for their peaceful needs; for thorough safeguarding and raising the welfare of the population."

(Cont'd on page 8)



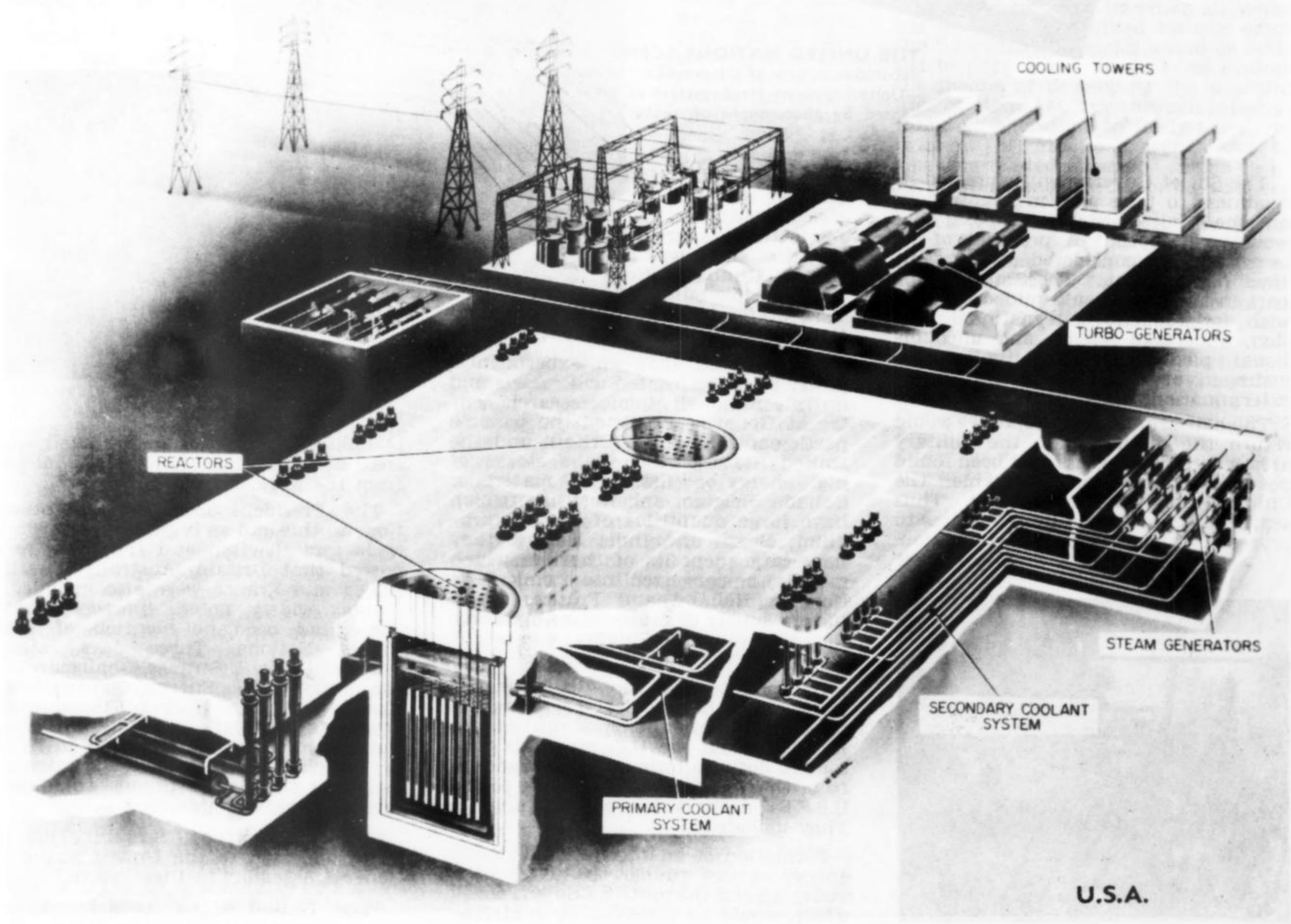
U. S. S. R.

ATOMIC POWER FOR PEACE is symbolized in the coat of arms adopted by Britain's newly created Atomic Energy Authority. Savage heraldic animals chained to the earth represent the power of the atom brought under control. The stars on each animal having a total of 92 points, symbolize uranium—No. "92" in the list of chemical elements. Inverted triangle on the shield is a heraldic symbol called a "pile" the first name for an atomic reactor or power furnace. The zig-zag lines represent the electricity developed from atomic energy. On top of the helmet, which is a symbol of co-operation, a sun signifies the benign power of the atom. The bird inside is a sign taken from the crest of the late Lord Rutherford, one of the world's most distinguished pioneers in nuclear research. The motto chosen by the Atomic Energy Authority, which forms part of this coat of arms, means : "The most from the smallest."

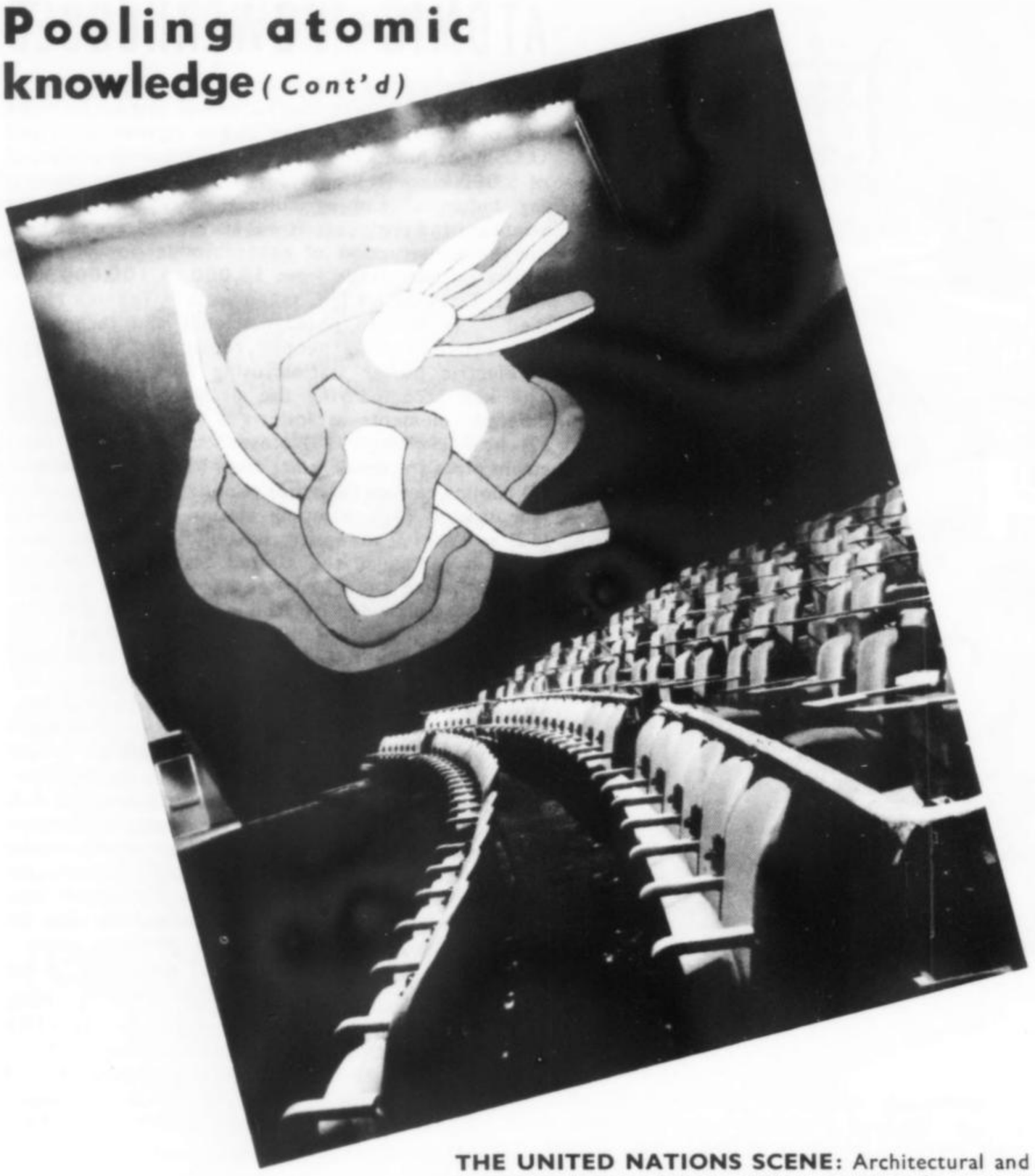


ATOMIC POWERHOUSES

A few months ago the Soviet authorities announced that the world's first electric power station to make use of atomic energy had begun operating in the U.S.S.R. on June 27, 1954. The plant, with an output of 5,000 kilowatts, provides electricity for neighbouring industrial and agricultural installations. Soviet scientists and engineers, it was also stated, are working on the construction of other atomic power plants whose outputs range from 50,000 to 100,000 kilowatts. Drawing on left, taken from " Teknika Molodieji ", (a Russian popular science and technology magazine for young people) represents " one type of electric power station using nuclear energy. " The key accompanying the drawing describes the different elements as follows : (1) atomic reactor (2) heat exchanger (3) steam condenser (4) main steam pipes (5) condenser pumps (6) turbo-generator (7) cooling towers (8) water cooling tank (9) transformer station (10) pumping station (11) workshops (12) stores (13) administrative buildings. Other countries, in particular the United States, and Britain, have for some time past been working on projects to use heat provided by atomic reactors to generate electricity. On September 6, 1954, work was begun on a commercial atomic power plant in Pennsylvania that is expected to provide electricity for 100,000 people. Artist's sketch (below) shows how two nuclear reactors might be used to produce electrical power from atomic energy. Such an arrangement might be one of the applications leading from an experimental programme now underway in the United States. Atomic fission in reactors, (centre and lower centre) would produce heat which would be transferred by liquid sodium through primary and secondary coolant systems to produce steam in the steam generators, (right). Steam would be used to power turbo-generators, (top) to produce electricity. About 200,000 kilowatts of electricity could be generated. *(Photo North American Aviation, Inc.)*



Pooling atomic knowledge *(Cont'd)*



THE UNITED NATIONS SCENE: Architectural and decorative beauty of the world's "workshop for peace" —United Nations Headquarters in New York—is highlighted by photographs on these pages. (U.N. photos)

The Soviet Government expressed its readiness to take part in negotiations on the United States proposal but would expect that a proposal of its own would be considered at the same time, namely that:" The States taking part in the agreement, guided by their wish for reducing international tension, undertake solemn and unconditional pledges not to use atomic, hydrogen or other weapons of mass extermination."

This disarmament proposal would return the discussion to the military area where no progress had been found possible in seven years and which the United States had tried to avoid. Thus sentiment grew in the United States to proceed without Soviet participation.

Mr. David Lilienthal, a private citizen but also the former chairman of the U.S. Atomic Energy Commission, for instance, suggested, late in December, that there was no time to be lost, that a United Nations agency could have the plan in operation by August 1954, preferably with Soviet participation but, if necessary, without.

He proposed that an experimental power plant be located at Brussels and an international atomic research centre at Geneva. He listed the possible participants as Great Britain and the United States, which have stocks of high-energy or "fissionable" materials; Canada, Belgium and Australia, which have large quantities of natural uranium; Brazil and India because they have large deposits of thorium which can also be converted into atomic fuel; Norway, Holland and France, which have a supply of radio-active materials for research and highly competent leaders in the atomic sciences.

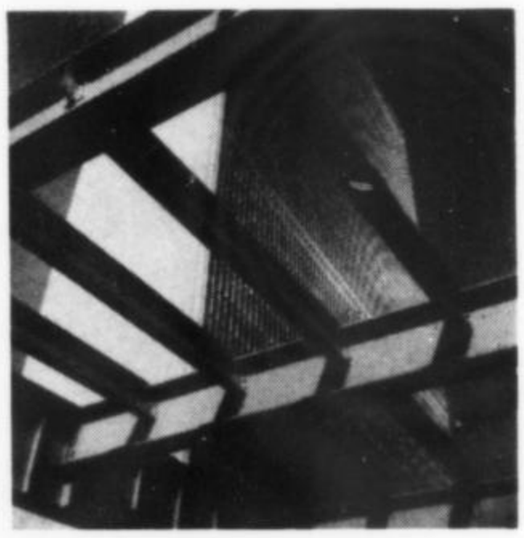
But private discussions between the U.S. and the Soviet Governments continued from January 2 until March 19, 1954, when the U.S. proposals took a more definite form in a memorandum from the U.S. Secretary of State to the U.S.S.R. Ambassador at Washington. They included:

Formation of an international atomic energy agency "under the terms of a treaty among the participating nations" which would be financed by contributions from the member states; its facilities would include storage of nuclear materials, control laboratories, administrative offices and such facilities "as might in time be necessary" for education and training, research and development, fuel fabrication and chemical processing.

Again the weeks passed until in April and early May, Soviet Foreign Minister Vyacheslav M. Molotov and U.S. Secretary of State John Foster Dulles conferred at Geneva and again failed to agree on the prohibition of atomic weapons as a preliminary to the establishment of the atomic power agency. This question was then referred to a new sub-committee of the United Nations Disarmament Commission which met—without result—in London in May. This seemed to mark the end of President Eisenhower's proposal to the United Nations as well as the failure of the Soviet effort for atomic disarmament.

As a result, American thought turned again to the development of peaceful atomic power without Soviet cooperation—and even without the United Nations. An emissary of the Atomic Energy Commission visited Brazil, Uruguay, Peru and Chile in August to discuss the feasibility of small atomic power plants in those countries.

On September 6, President Eisenhower participated in the start of construction on a commercial atomic power plant in Pennsylvania that is expected to provide electricity for 100 000 people. On this occasion he announced that the United States had agreed with "a number of other nations to go ahead now with the formation of an international agency which will foster the growth and spread of the new atomic



technology for peaceful use... We hope that no nation will long stand aloof from the work of this agency."

The President mentioned negotiations to this end as beginning with Canada and Belgium and the press reported that Britain, Australia, South Africa and France were also included. It was widely noted, however, that there had been no mention of the United Nations. Three days later, Admiral Lewis S. Strauss, Chairman of the U.S. Atomic Energy Commission, stated that the United States was preparing to call an international conference of nuclear scientists in 1955 in which all interested countries, including the Soviet Union, would be invited to participate.

But on September 23, Secretary Dulles again appealed to the United Nations General Assembly in these words:

"The United States is determined

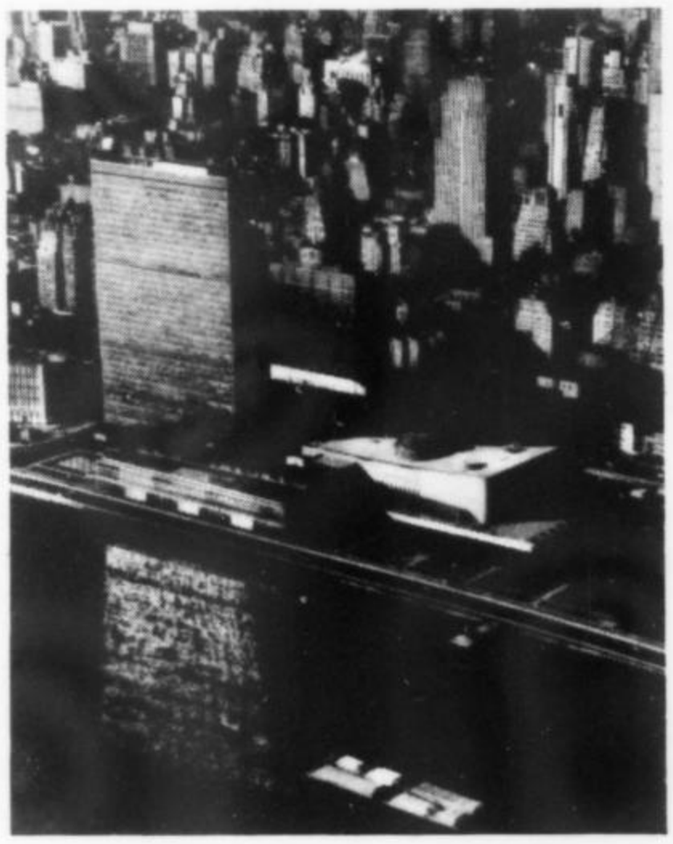
that President Eisenhower's proposal shall not languish until it dies. We are determined that it shall be nurtured and developed. And we shall press on in close partnership with those nations which, inspired by the ideals of the United Nations, can make this great new force a tool of humanitarianism and of statesmanship and not merely a fearsome addition to the arsenal of war.

"The United States is here proposing an agenda item which will enable us to report further on our efforts to explore and to develop the vast possibilities for the peaceful uses of atomic energy. These efforts have been and will be directed primarily toward the following ends:

(1) The creation of an international agency, whose initial membership will include nations from all regions of the world. And it is hoped that such an agency will start its work as early as next year.

(2) The calling of an international scientific conference to consider this whole vast subject, to meet in the spring of 1955, under the auspices of the United Nations.

(3) The opening early next year, in the United States, of a reactor training school where students from abroad may learn the working principles of atomic energy with specific regard to its peacetime uses.



(4) The invitation to a substantial number of medical and surgical experts from abroad to participate in the work of our cancer hospitals in which atomic energy techniques are among the most hopeful approaches to controlling this menace to mankind. "I would like to make it perfectly clear that our planning excludes no nation from participation in this great venture. As our proposals take shape, all nations interested in participating and willing to take on the responsibilities of membership will be welcome to join with us in the planning and the execution of this programme."

The response to the American proposal before the General Assembly was immediate and favourable. After almost ten months of delay, during which the fear of the atom had grown throughout the world, the members of the Assembly showed eagerness to make a start in the opposite direction. On the following day, Mr. Vishinsky expressed the approval of the Soviet Delegation for incorporating the American statement in the agenda and asked for unanimous approval by the General Assembly in favour of studying the United States proposal. The report mentioned by Mr. Dulles was immediately referred to the Political and Security Committee of the General Assembly. In a few days, a number of nations endorsed the U.S. proposal.

Then, on October 1, a study of the proposal was begun by a special UN committee, headed by Dr. Ralph J. Bunche, who has been named as Under-Secretary of the U.N. Secretariat. At the same time, Mr. Henry Cabot Lodge, Jr., permanent U.S. representative at the United Nations, said at a press conference that the United States would submit a resolution to the General Assembly asking the United Nations to call a conference of scientists and others to settle the details of the new agency. He said that the United States would suggest that the entire programme be placed in the hands of a new agency similar to the World Health Organization, for instance, which would decide on its own relations with the United Nations.

On November 5, Mr. Lodge addressed the Political and Security Committee to propose the organization of such an agency. A draft of the resolution was submitted jointly by Australia, Belgium, Canada, France, South Africa, Britain and the United States. The resolution suggested that a technical conference be held not later than August 1955 at a place to be selected by the Secretary-General and an advisory committee.

On November 12, Mr. Vishinsky addressed the Committee and stated that he would vote for the resolution provided the proposed international agency were placed under the U.N. Security Council instead of having the separate status of a specialized agency. This was on the ground that the production of atomic materials for peaceful purposes would increase the amount available for weapons and that the production of radio-isotopes would itself have military importance.

This Soviet proposal lead to further long discussions.

Unexpected action by the United States on November 15 had the effect of bringing the discussion to a conclusion. On that day, Mr. Lodge told the Political and Security Committee that the U.S. Atomic Energy Commission had allocated 100 kilogrammes (220 lbs) of fissionable material for use by the proposed international agency. This material could be used in a considerable number of small experimental atomic reactors, but it could not be put to use in the form of weapons.

On the next day, Anthony Nutting, Head of the British Delegation to the General Assembly, announced that the British Government would hold available 20 kilogrammes (44 pounds) to be used by the international agency as fuel in experimental atomic reactors. The composition of the advisory committee for the creation of the international agency was announced as: United States, Soviet Union, Britain, France, Canada, Brazil and India, and Mr. Vishinsky accepted for the U.S.S.R. the invitation to serve on this committee. This was taken to mean that the Soviet Union would participate in the conference planned for 1955.

Finally, on November 23, the Political and Security Committee of the United Nations voted unanimously to endorse the proposal as made by the seven nations: United States, Britain, France, Canada, Australia, Belgium and South Africa. The resolution thus unanimously carried expresses the hope that "international co-operation in developing and expanding the peaceful uses of atomic energy will assist in lifting the burdens of hunger, poverty and disease" and suggests that "once the agency is established, it negotiate an appropriate form of agreement with the United Nations, similar to those of the Specialized Agencies"

With respect to the international conference on the peaceful uses of atomic energy, the decision was made that "an international technical conference should be held under the auspices of the United Nations" in which all Member States of the United Nations or of the Specialized Agencies would be invited to participate "in order to explore the means of developing the peaceful uses of atomic energy through international co-operation, to study the development of atomic power", and to consider related questions in the technical areas and fundamental sciences.

The resolution requested the Secretary-General to call such a conference not later than August 1955, and suggested preliminary consultations "with the competent specialized agencies, in particular FAO, WHO and UNESCO".

One final formal action was needed, namely the approval of this committee action by the entire membership of the General Assembly. This was done by unanimous vote on December 4, just under a year after President Eisenhower made his historic proposal.

THE POWER-PACKED ATOM

It could end the world's shortage of energy

RAW MATERIAL of atomic energy is plentiful in France. Here official of the French Atomic Energy Commissariat is examining a sample of pitchblende (uranium bearing ore). Map behind him shows locations of uranium deposits. These deposits in France as well as others of thorium and beryllium in Madagascar have been important factors in the development of France's atomic energy programme.

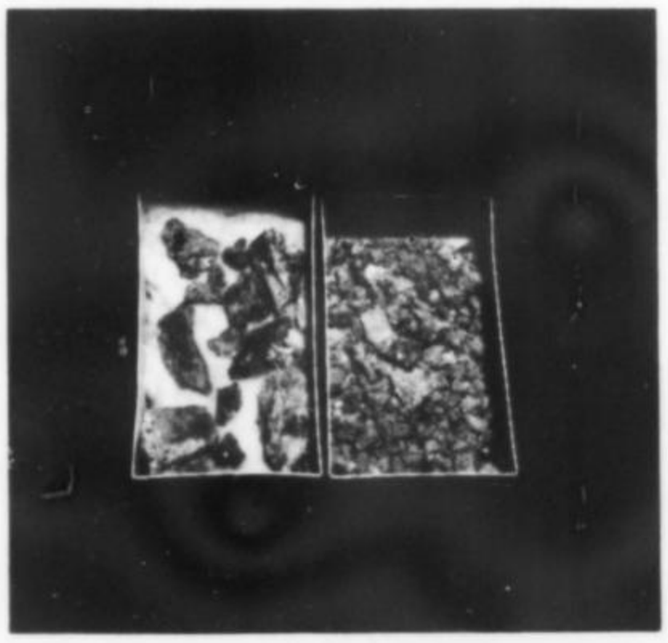
As a man needs food to stay alive, so modern urban, civilized living demands energy for its sustenance. Energy is hard to define, since it is not a thing and has no size or weight. It is the basis of action, the capacity for doing work. It is the difference between an object in motion and one at rest, the difference between hot, expanding steam and cold water, between coal that can burn and rocks that cannot.

In each case the first material contains energy which it loses in action. Invisible and intangible, energy is responsible for anything and everything that *happens* in the universe.

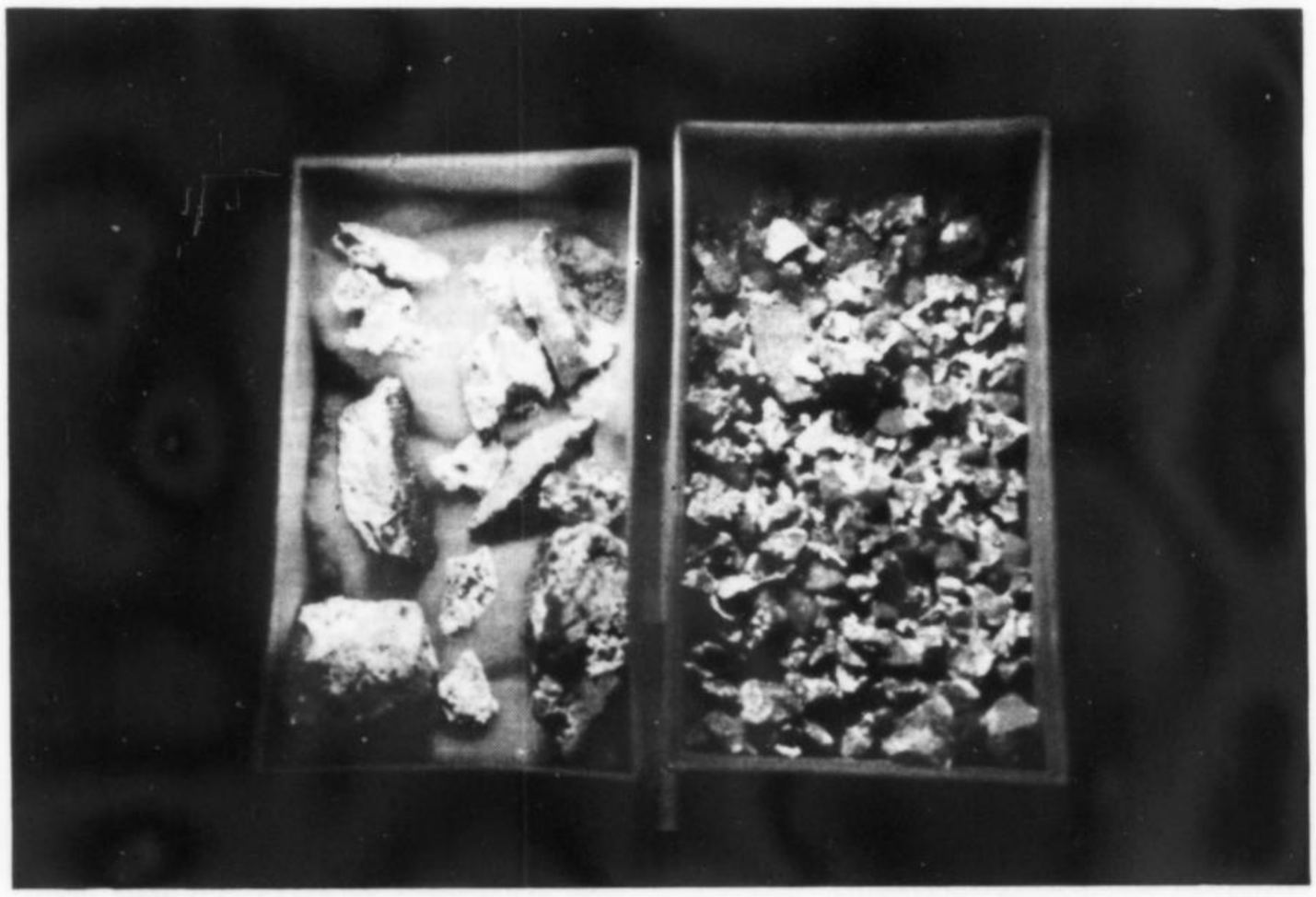
Men and animals get energy from the food they eat. In a primitive society that energy is enough for a day's work, but in most parts of the world a man can barely support himself and his family by the work of his own muscles. A horse, camel or bullock increases his production and his wealth. In an organized society, light and warmth, transportation and manufacturing must all be supplied from fuels, the wind, or energy from the sun. The more industrial a society is, the more it needs energy and the "development" of a country requires first of all a supply of energy.

A pound of bread or of rice provides about 1,200 calories to the human body. Two or three pounds of food a day—2,500 to 3,000 calories—furnish the energy that is needed for an ordinary day's work. This, plus a little more for cooking or for warmth, is enough for a simple life. But an industrialized country needs far more energy.

In the U.S.A., for instance, the total for each person is 172,000 calories per day. This is almost sixty times the



THE BEST SAMPLES of uranium ore can be selected by exposing them to ultra-violet rays. Here (photo above) a sample of uranium ore is shown as it appears in ordinary light. Subjected to ultra-violet rays (photo right) it gives off a strong luminosity which is proportional to the quality of the uranium it contains.



energy that a man generates, so that in such countries every man, woman and child has the equivalent of sixty labourers working for him.

In the discussion of the United Nations project for the use of atomic energy, M. Jules Moch, French delegate and former Minister of the Interior, discussed the growing need for energy in all the countries of the earth. In the major industrial countries the use of power doubled during the first third of this century and at present is about half a horsepower per person. In the U.S.A. the power used in factories, excluding transportation and motors, was only 0.19 horsepower per person in 1909 but 0.50 horsepower in 1950. This is approximately 400 times the power demand in the underdeveloped territories of Asia, Africa and America.

For the world as a whole, the average use for power per man is now only one sixth of that in the U.S.A. Hence if the industrialization of the rest of the world is to reach the level prevalent in North America, the total energy available will have to be multiplied at least six times over. Expressed in terms of coal, the production would have to be increased from 2,500 million tons to 15,000 million tons per year. The average American uses 8 tons of coal a year, the European, 2.2, whereas the man in a practically underdeveloped country only makes use of 0.02 tons. This is another way of saying that the most industrialized countries use 400 times as much energy per person as do the least developed.

If the world's consumption of fuels were doubled, to say nothing of being multiplied sixfold, our underground resources would soon prove inadequate. The oil and natural gas will last for only decades and the coal for some centuries. Yet in the industrial countries the coal of high quality that is easily mined is already becoming exhausted, so that at best the cost of coal will increase and its quality will decrease. For this reason far-seeing engineers are gravely concerned over the future of the industries that depend on underground fuels.

But what is more important is the striking disparity in the coal resources available in different countries. An industrial future is hardly possible for countries that have little coal or oil. To transport a hundred million tons of coal for thousands of miles would incur a cost of a thousand million dollars for freight alone. It is a prohibitive cost.

It is for this reason that the newly created resource of atomic energy is attractive. If the atom can be harnessed to provide the energy, the industrialized countries need not fear the increasing cost and decreasing supply of coal. The countries that have no coal can hope to compete at once even if its cost is higher than the present cost of energy in the industrial countries.

A striking example is the situation of so highly industrial a country as Switzerland. The economy of that country is based on water power generated from the ample Alpine streams. Yet Switzerland faces a future in which this power will not be enough to meet its needs.

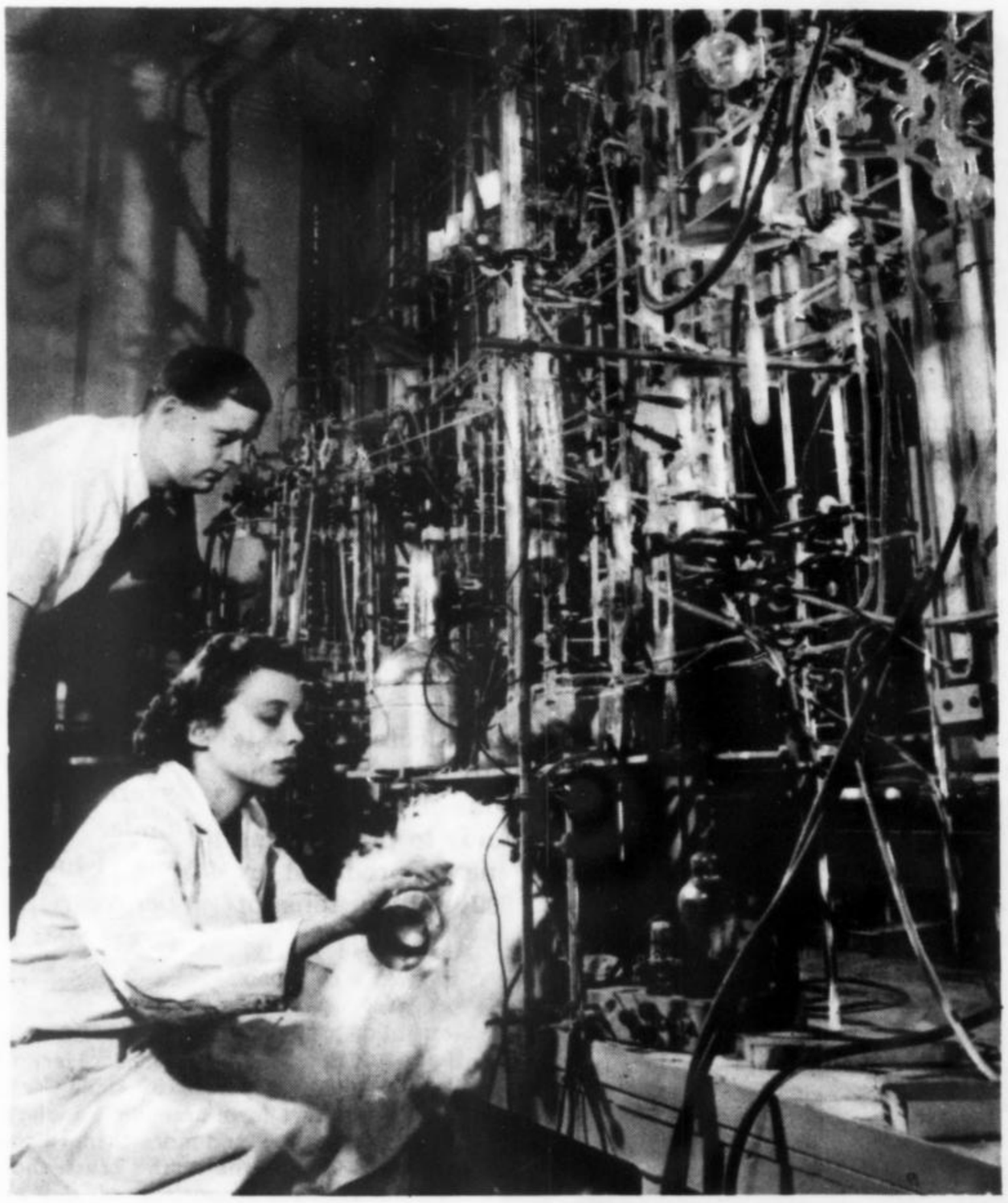
Recently, Mr. Alfred Winiger described the situation to representatives of Swiss electrical industries. He foresees a continuing increase in the demand for energy of about 3.8 % per year. On the basis of this estimate he concludes that : "By 1975 the demand for energy in Switzerland will no longer be met by our hydraulic resources, which are today used at 50 % of the total available. According to circumstances, we should have new sources of energy at our disposal between 1970 and 1975 if we wish to avoid being too dependent on foreign sources for our energy requirements.

"Taking these factors into consideration, it is quite logical that we should turn to nuclear reactors for our future source of energy. We should then continue to depend on foreign sources for the delivery of atomic fuel, but, on the other hand, the cost of transport of the fuel, which at present weighs heavily on our economy, should be virtually eliminated. In effect, a ton of uranium, used to the maximum, produces as much heat as 3 million tons of coal. To transport this coal from the mines of the Ruhr to Zurich would alone cost nearly 120 million Swiss francs, plus the cost of storage. The saving in transport costs would permit us to lighten considerably our balance of payments abroad."

M. Jules Moch, speaking to the General Assembly of the United Nations said:

"These considerations point out the direction to be taken by human effort. If the standard of living of the underdeveloped majority of mankind is to be increased and if the standard of living of the industrialized minority is to be maintained and improved man must—and soon—exploit new power resources. The achievement of that goal is, in the last analysis, the very condition of social progress.

"Does atomic energy offer a solution to this problem of replacing exhausted or decreasing power resources? Theoretically, this is no doubt true... The total annihilation of a gramme of material, any material, would release the power equivalent to that released by the burning of 20 million tons of coal. The present needs of all mankind, counted in millions of tons



PROBING NATURE'S SECRETS: One day energy from the atom will help to ease the drain on such natural fuels as oil, coal and natural gas, on which the demands of industry and modern life are making ever-greater inroads. In the meantime scientists are experimenting with the production of synthetic fuels. Here, two scientists of the Gulf Oil Company, in Pennsylvania, probe into the still mysterious reaction by which petrol is made from coal. They use radio-isotopes as "tracers". (Photo, Gulf Oil Co.)

ENOUGH FUEL FOR CENTURIES *(Cont'd)*

PROSPECTOR of the atomic age uses a Geiger-Muller counter — an instrument which measures intensity of rays given off by radio-active substances—to detect the presence of uranium-bearing ores. (Photo USIS.)

of coal, would thus be realized by the disintegration of 300 pounds of matter.

"However, we do not yet know how completely to annihilate a particle of matter and turn it into energy. Perhaps not even our descendants will know how to do so. The phenomenon of fission obliterates less than one-thousandth part of the materials involved. The phenomenon of fusion, if it could be carried out in a slowed-down manner, would bring about the disappearance of less than a hundredth part of the materials involved.

"We should therefore have to subject to fission masses of material one thousand times larger than the quantities I have just mentioned in order to produce the same amount of energy and power. In other words, we would have to operate in terms of tons rather than in terms of pounds. In fact, still speaking theoretically, it would be necessary to bring about the fission of 130 long tons of uranium 235, rather than 300 pounds to produce the equivalent of the energy produced by the burning of 2,500 million tons of coal.

"Let us suppose that fission becomes industrially feasible in a number of years. It is not so today and... we have still a few years to go. Let us also assume that a procedure can be used that is still in the experimental stage, the "breeder" procedure (*see page* 21). Let us also suppose that the output of this operation in a certain number of years reached 50 per cent efficiency, under these conditions the reaction would have to use 300 tons of material per year in order to produce the total power now being used. However, since

URANIUM MINE near Limouzat, France, is one of several being worked by the Research and Mining Operations Branch of the French Atomic Energy Commissariat (C.E.A.). Uranium has been known since 1789 when a German chemist, Martin Klaproth, discovered an oxide of this element and named it after the planet Uranus. But a French chemist, Eugène Péligot, in 1841, was the first to isolate pure uranium.

EXTRACTION TOWER at a uranium mine in the Puy-de-Dôme, Central France. Here the ore is brought to the surface and transported by cable car to nearby processing plant. In its pure form uranium is a white metallic element, slightly softer than steel and more than 18 times as heavy as water. It occurs widely in the earth's crust, though most minerals contain only a small proportion of the element.

we cannot hope for such technical progress except after a lapse of a number of years, we must envisage a doubling of the power consumption over the same period, and it would be necessary to have natural uranium at our disposal, as well as thorium, at the rate of 600 tons per year.

"And finally, in order to give the peoples of the world the American level of industrialization, the quantity required would be almost 4,000 tons per annum. Since fruitful breeder materials are involved, these figures can be reached without any insurmountable difficulties, but the technical procedures must still be perfected and, therefore, the general use of atomic energy by this process, which as yet has not been fully explored can be carried out only gradually.

"Let us, therefore, forego any exaggerated hopes. And here we come to the core of the problem. The advantages of this process, as regards the underdeveloped areas of the world, are incalculable. The 600 tons of uranium which I previously envisaged would correspond to a doubling of today's consumption of fuel, equivalent to the consumption of 5,000 million tons of coal. With an extraction rate of 1 per cent of metal, the 600 tons of uranium would require 60,000 tons of ore, which is a tonnage 80,000 times less than that of the coal that would be required to produce the same energy.

"The transition from the thermal era to the atomic era would thus take the form of a reduction, by a ratio of 80,000 to 1, of the weight of the materials or ores to be extracted, and a reduction of 100 times larger would make the ratio 8 million to 1 in the weight of the fuel to be transported from the mine to the furnace. Atomic power thus appears to be easily dispersable and transferable into regions lacking in other resources.

"This sort of dissemination doubtless would spell immense social progress in making available large power resources to all peoples. In the same manner, the portable reactors now being built in America—which are known by the striking and expressive name of "power package"— constitute a happy augury for the international proletarization, if I may so call it, of power to be placed at the disposal of mankind.

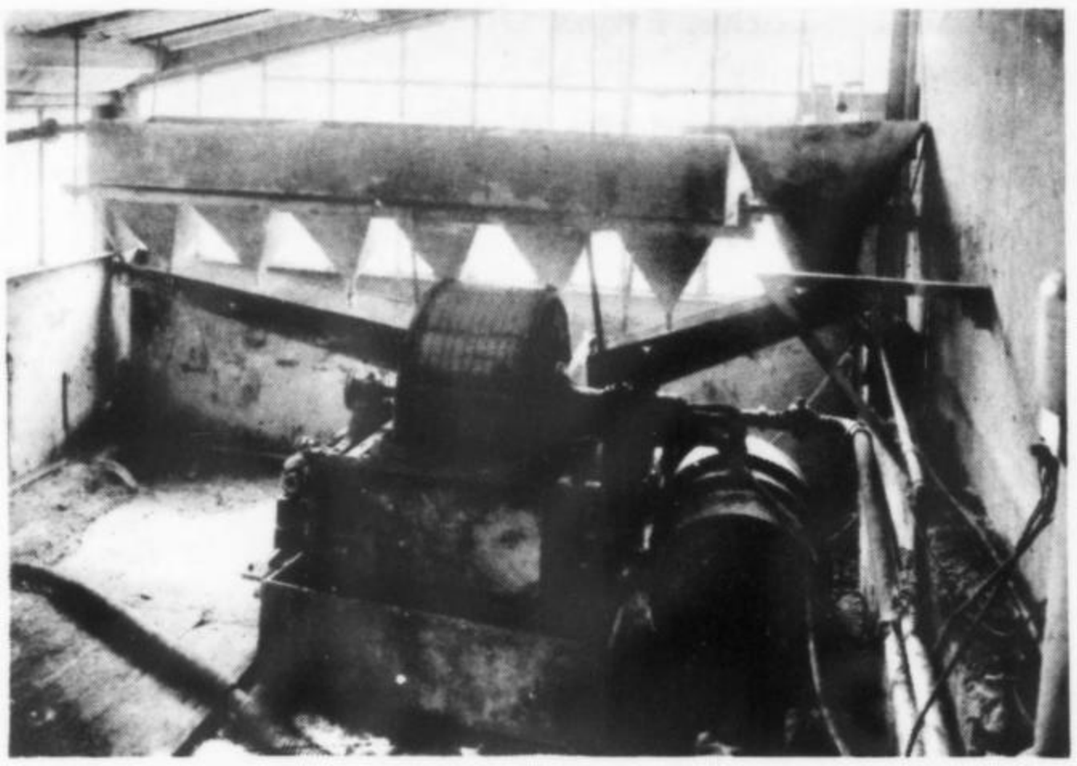
"One hurdle remains, and that is the question of cost. It is certainly rash to prophesy, since we do not know the cost of atomic power production in large central plants which would utilize breeder and fissionable materials at the same time We do not know to what point the progressive exhaustion of coal and of oil resources will raise the price of conventional power sources. Comparisons of future prices are still impossible, and we must therefore limit ourselves to the present day, even though we are fully aware that the present data will not apply tomorrow.

"Today, the cost of power produced in large American power plants using coal is in the region of .4 cents per kilowatt hour. The average for other countries is between .5 and .6 cents per kilowatt hour, according to the study carried out by Professor Weinberg in May 1953. In England, the cost of electric current over the same period was .8 cents and the price at which it was sold to industry was between 1.1 and 1.3 cents per kilowatt hour. I shall not cite the French figures, because we are rather poorly endowed so far as power costs and power resources are concerned. It might be hoped that in the near future a cost of .7 cents or .8 cents per kilowatt hour could be achieved by means of atomic energy if such projects were realized in conformity with the hopes of their sponsors, and it might be supposed that atomic energy would rapidly compete with conventional energy sources, even in those countries where the latter are low in cost.

"The ease of transportation... would give atomic energy this rare virtue of being saleable everywhere at the same prices or at just about the same prices. It would therefore be the main power resource of countries where conventional power sources are scarce or costly, that is to say, essentially in most of the under-developed areas of the globe. Perhaps an international organization, prompted by some feeling of international solidarity, might assign some sort of priority to the latter areas.

"But even if atomic energy were to become competitive, the fact would remain that the transition from the classical power era to the atomic power era will be a gradual and prolonged one."

M. JULES MOCH of France, told the U. N. General Assembly that in theory atomic energy can solve the problem of replacing exhausted or decreasing power resources, but that transition from the classical power era to that of atomic energy would be gradual and prolonged. (U. N. photo.)



ORE - WASHING MACHINE in uranium processing plant at Lachaux, Central France. Unlike most metals uranium is not extracted by smelting the ore, but by putting it through series of processes, involving dissolving, filtering and precipitation, during which the wanted elements are separated from the unwanted. Finally the uranium is brought down to a solid salt and from this it can be reduced to a metal.

METALLIC URANIUM being produced in a plant at Bouchet, near Paris. The solid uranium compound, now highly purified, is mixed with chips of calcium metal in a mould and fired, and thus reduced to a metal. The metal reduction process, one phase of which is shown here, is one of the most striking aspects of uranium production. (Photos C. E. A.)

HOW NATIONS WILL WORK TOGETHER

"The entire world will rejoice", said Dr. Eelco N. Van Kleffens, President of the U. N. General Assembly, commenting on the decision which opened the way to international co-operation in the use of the atom.

ON December 4, 1954, the atomic age entered into a new and promising phase. Meeting in New York on that day, the General Assembly of the United Nations unanimously adopted a seven-nation resolution for the international development of atomic energy for peaceful uses and expressed the hope that an international atomic energy agency would be set up without delay.

About the same time, the General Conference of Unesco, meeting in Montevideo, had proposals from India, France and Japan to undertake studies on atomic energy, isotopes and radiation effects. It delayed action, however, until the United Nations' decision had been made, then adopted a programme to accord with it. "This is a matter of momentous importance", said Dr. Luther Evans, Unesco's Director-General, "Unesco must respond to this great opportunity".

A full account of the United Nations action and the discussion that preceded it is given in the article on page 5 of this issue. Here are the main features of the projects adopted by the United Nations and by Unesco :

THE UNITED NATIONS

Two separate projects are authorized, not formally connected with each other :

The International Atomic Energy Agency

This will be organized in joint discussions between the seven nations who sponsored the U.N. resolution : Australia, Belgium, Canada, France, Great Britain, South Africa, and the United States, and others that desire to join. All states that are members of the United Nations or of one of the Specialized Agencies will be eligible to membership. It will be financed by its member states, as are the existing Specialized Agencies such as the Food and Agriculture Organization in Rome, the World Health Organization in Geneva, and UNESCO in Paris. Once established, it will negotiate an appropriate form of agreement with the United Nations, and it is thus expected to become one of the Specialized Agencies.

As conceived by the General Assembly the agency will act as international broker for the allocation of fissile, or atomic-energy materials, and will study and supervise the world-wide use of atomic energy for industrial power and of atomic materials and isotopes for research and scientific applications. It may also undertake the training of specialists in nuclear science. Its work will be related to that of the atomic energy commissions of member states, the European Centre for Nuclear Research in Geneva, and the existing Specialized Agencies of the United Nations.

Conference on Peaceful Uses of Atom

The Secretary-General of the United Nations will call an international conference to be held not later than August 1955, to "explore means of developing the peaceful uses of atomic energy through international co-operation and, in particular, to study the development of atomic power and to consider other technical areas—such as biology, medicine, radiation protection, and fundamental science—in which international co-operation might most effectively be accomplished.

The Secretary-General will have the advice of a committee composed of representatives of Brazil, Canada, France, India, the U.S.S.R., the United Kingdom and the U.S.A. in selecting the place of meeting, in issuing invitations, and in preparing a detailed agenda for the conference. The Specialized Agencies, in particular FAO, WHO, and UNESCO, will be consulted in connexion with the planning of the conference and will be represented at it.

The conference will cover the wide variety of topics that are touched by this new phase of science, including those discussed in the articles in this issue of the UNESCO COURIER. It may discuss the functions of the international atomic energy agency. But the agency does not need to await the report of the conference and there is some international enthusiasm for the establishment of the agency in the immediate future, well before August.

UNESCO

Unesco's own function in support of the United Nations' atomic energy programme has three phases :

Research Co-operation

UNESCO is the United Nations Specialized Agency especially responsible for the promotion of international co-operation in science, and in particular for research and training and the diffusion of scientific knowledge. It was responsible for the establishment of the European Centre for Nuclear Research and will now assist in the preparation of the scientific aspects of the international conference. UNESCO will also assist other U.N. Specialized Agencies, such as the World Health Organization, in studying the effects of radio-activity on life in general. It will continue to study ways of aiding international scientific co-operation in such questions as the use of radio-isotopes in research and industry. It may prepare preliminary reports on scientific subjects that are essential to both the conference and the atomic energy agency, and will be ready to carry out conference suggestions relating to international research co-operation.

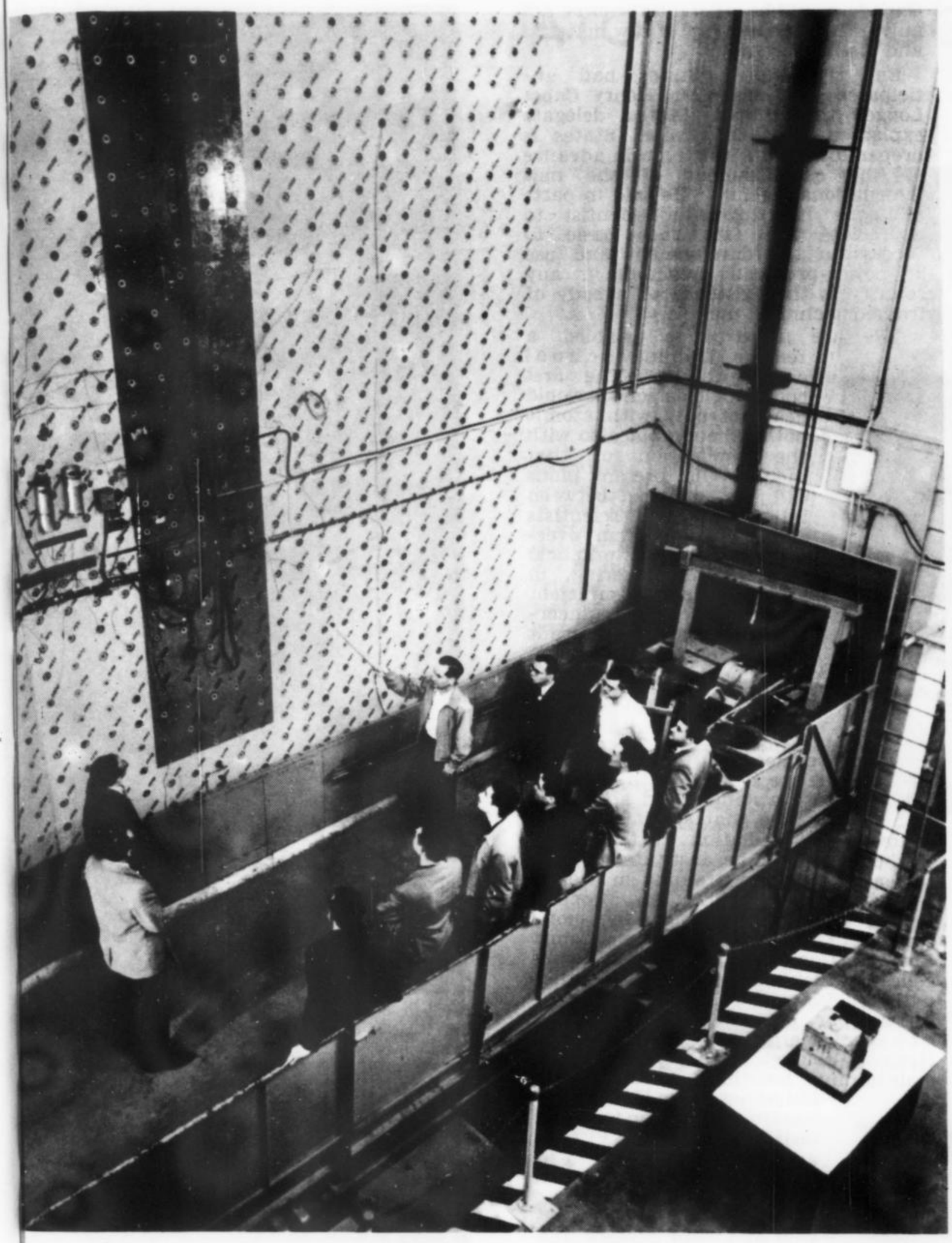
Scientific Training

The conference and the international atomic energy agency will certainly provide a stimulus to scientific education and technical training in many parts of the world. Even in the industrialized nations, there is already a grave shortage of competent science teachers. The sudden dawn of an atomic age will create an emergency demand for vocational training, for science teaching in the secondary schools and for specialized courses in the universities of almost all nations. UNESCO will expand its services in these fields, particularly in the underdeveloped countries. It will hold a workshop conference on vocational training in the Middle East in 1956. In addition, UNESCO will prepare manual and visual aids for the introduction of the facts and concepts of atomic energy, radiation and radio-active materials into school science teaching.

Public Education

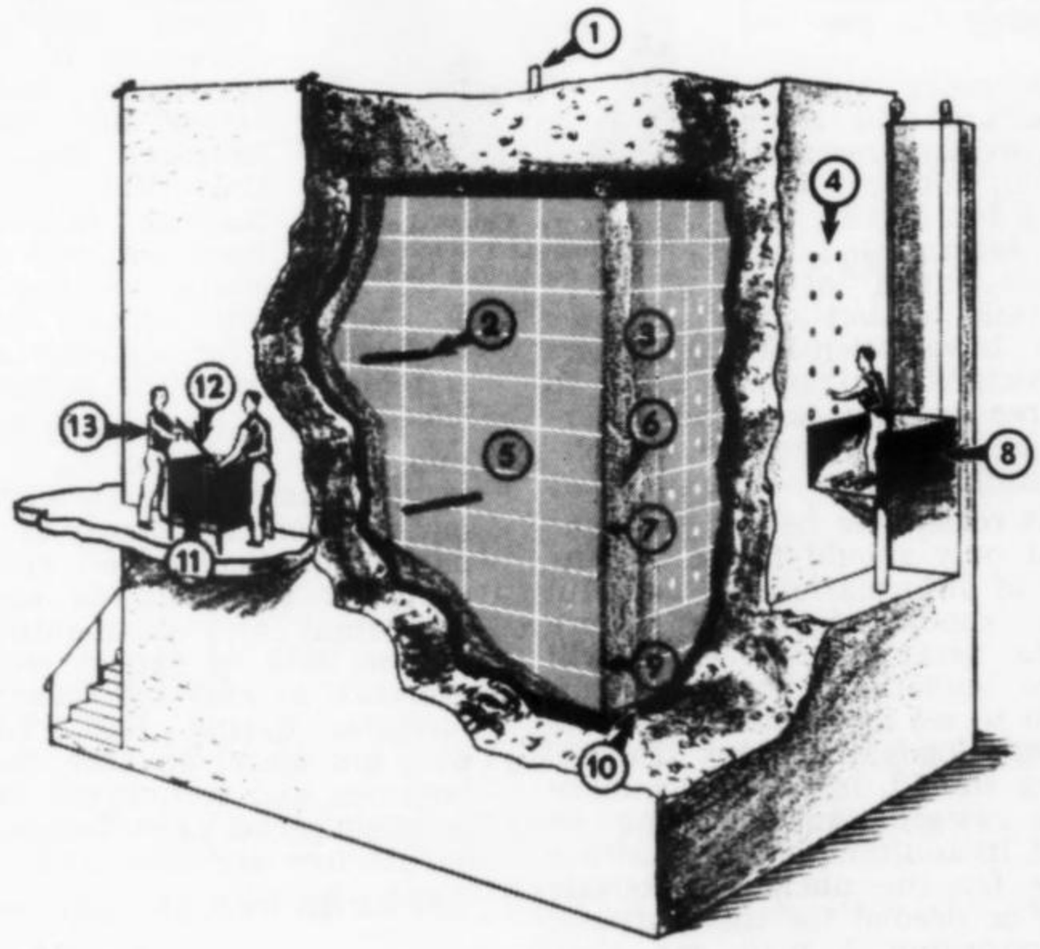
The large public expenditures necessary for the development of atomic power in many nations will demand informed public support. The fruitful application of the results of atomic research in agriculture, medicine and industry also require public understanding. Most of all, the economic and social consequences of the imminent power-revolution in countries that have not yet felt the impact of technology demand foresight in government and a broad incorporation of science into cultures. The atom can become a friend to humanity only when it is universally understood and welcomed. UNESCO will call two conferences on the public understanding of science, with the participation of national science associations, science writers, and science teachers. One will be held in Europe in 1955, the other in Latin America in 1956. The media of public education will be widely used, as is exemplified by this issue of the UNESCO COURIER.

Training the technicians of the new atomic age



NUCLEAR STUDIES CLASS at Oak Ridge National Laboratory, U.S.A. (left). Instructor explains main features of the Laboratory's ten-year-old graphite reactor. Since 1948, Oak Ridge has given instruction courses in peaceful uses of the atom to well over 1,000 scientists, technicians and engineers both from the U.S.A. and other countries. The wide application of atomic energy for peaceful purposes will involve large-scale training of scientists and engineers, and also broad educational campaigns to create an understanding of the atom and its peaceful uses.

Model of the same Oak Ridge reactor (below, left) has shown people in the United States how atomic energy is generated, and how radio-isotopes are produced for use in medicine, industry and agriculture. Sketch (below,) shows some details of this reactor : (1) Boron steel control rod (2) Long graphite holders (3) Graphite moderator in which aluminium rods containing uranium are inserted. Chain reaction takes place here (4) Uranium slugs are introduced here (5) Holes for aluminium tubes (6) Aluminium tubes containing uranium (7) Graphite moderator (8) Elevator (9) Graphite reflector (10) Cooling air circulation space (11) Lead protective screen (12) Removal of aluminium tubes containing isotopes (13) Concrete protective casing. (Photos USIS).



THE atomic power project of the United Nations carries a promise of great and real boons, even of an effective social revolution in many lands. But a closer view reveals its magnitude and complexity. It is not merely a matter of the distribution of nuclear fuels and the building of atomic furnaces. Those powerful new forces need to be understood and managed by many men in many nations who are fully trained in their erudite principles and their intricate and dangerous techniques.

Yet the heritage of war and the years of secrecy have given only a few countries adequate knowledge in this field while most countries have little or none. It is obvious that the engineering and production operations must be preceded by a period of intensive training and education in those countries that are to participate. Several years of preparatory education may well be needed.

Even in the early United Nations debate this was made clear by Mr. Paul Martin, the Canadian delegate, who said:

Mr. Paul J. Martin, Canadian Delegate to the United Nations General Assembly.

"The most immediate need is for information and training to spread the technology required for the application of atomic energy for peaceful purposes on a wide scale. It would be visionary to imagine that if by this time next year the international agency had been set up it would shortly thereafter be in a position to start exporting power reactors, for instance, to various parts of the world... I say this as plainly as I can to prevent possible misconceptions being followed by a certain disillusionment.

"The Canadian Government does hope, however, that the agency, when established, would assist other countries participating in the agency's programme to set up their own research reactors and to join with those countries already possessing them in pressing forward with the search for developing atomic power on an economic basis and with the whole range of other actual and potential applications of atomic energy for peaceful purposes.

Mr. Henry Cabot Lodge, Permanent U.S. Representative to the United Nations.

"And in order to construct reactors and carry on useful creative research in this field, not only is it necessary to have the technical information on the subject—much of it already available—but one must also have scientists, engineers and technicians trained at least to some degree in the use and interpretation of these extremely complicated research tools.

"For this reason we believe that the agency not only should foster the interchange of information on peaceful uses but should facilitate where possible the arrangements which will have to be made for those countries which wish to set up research reactors to have their people suitably trained. The agency should, in fact, encourage world-wide research and development and should, in addition, be in a position to arrange for the nuclear materials which will be needed for this purpose. In this connexion I may say that Canada would be a potential source not only of information but of raw material and fissile material."

But the United States had anticipated this need. Mr. Henry Cabot Lodge, the United States delegate explained what the United States is prepared to do in 1955, even in advance of the establishment of the new international agency. He said in part: "No one has to be a scientist to appreciate the fact that basic to success in the development and use of power-producing reactors in any country is the existence of a body of trained technical men.

"We are prepared to establish a reactor training school early in 1955. The first course of this school would deal not only with atomic power theory, but also with the application of that theory. Our present plans call for inviting between thirty and fifty scientists and engineers from overseas to study practical reactor engineering, in order to furnish sufficient basic science and engineering knowledge to permit the members of this group not only to understand the theory, but also to become competent to operate reactors...

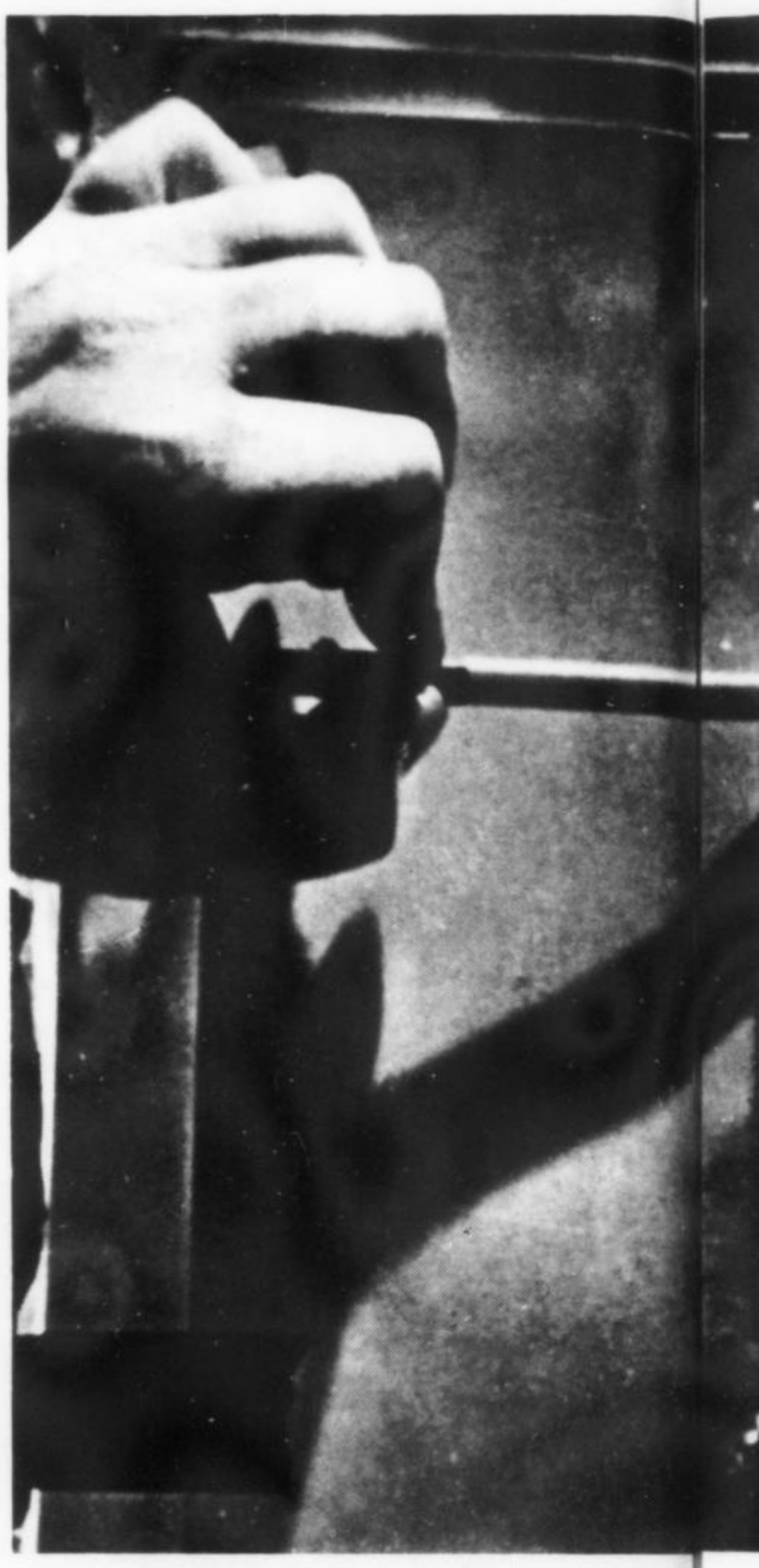
"Second comes the field of safety. Because we are dealing with a power which is both a danger and a boon, it is necessary also that special training courses in radiation safety and medicine should be instituted simultaneously with any training in atomic power development. We propose, therefore, to establish under the sponsorship of the United States Atomic Energy Commission the following courses, which will be open to all other nations; Industrial Medicine—a one-to-two-year course... concerned with atomic energy activity; Industrial Hygiene—courses in the techniques of maintaining healthful conditions in industries dealing with hazardous atomic materials; Radiological Physics and the theory and use of radiation instruments...

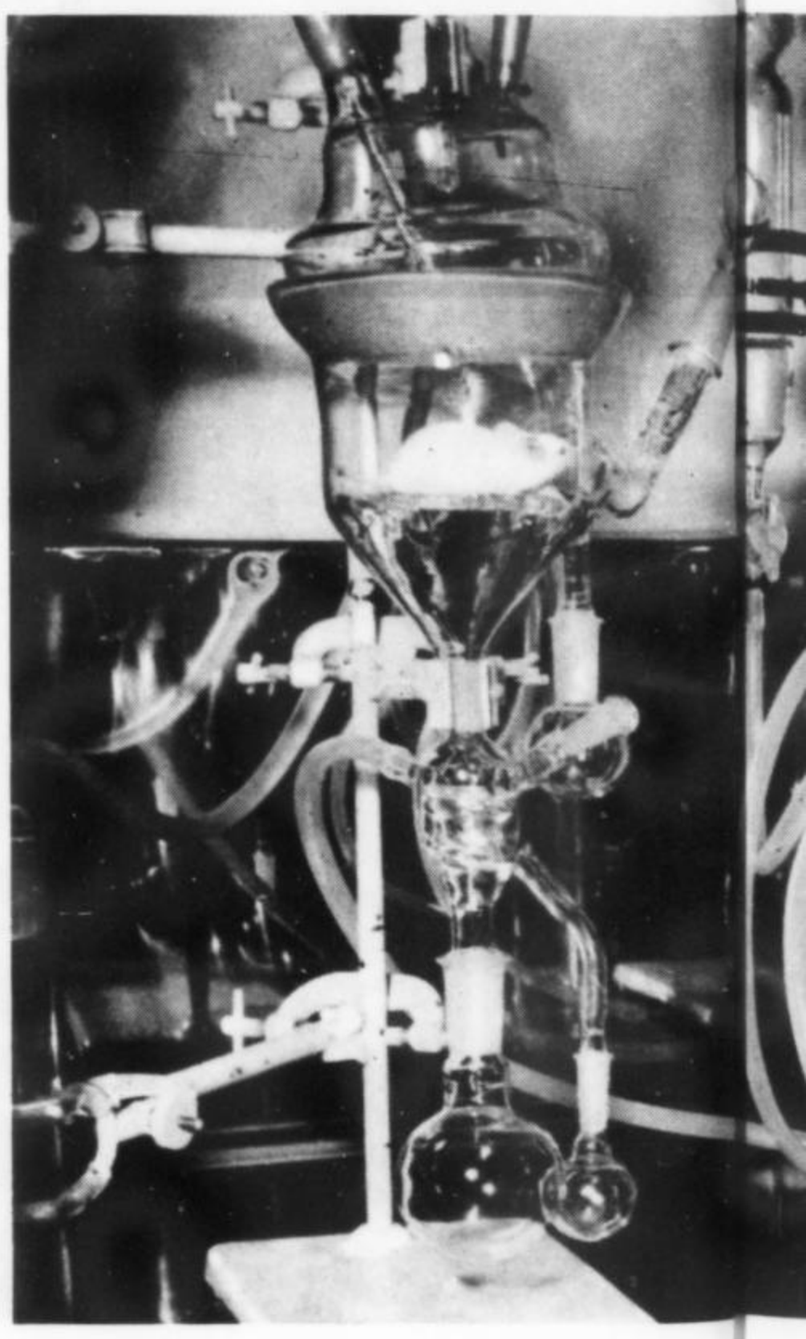
"Third in our training programme comes the vast field of atomic biology and medicine. The Argonne Cancer Hospital at the University of Chicago, the Brookhaven National Laboratory, and the Cancer Research Hospital at the Oak Ridge Institute of Nuclear Studies will be open for one to two-year courses on the use of atomic energy in medicine and biology, for approximately five to ten foreign students per course.

"The field of cancer is so important, and other countries have made such strides, that we do not wish to restrict our collaboration simply to the study of our techniques. We are therefore prepared to invite as many as 150 competent and distinguished visitors in the field of cancer research from overseas to visit our cancer research facilities during 1955. These guests will not only be free to study our facilities and techniques, but will also be encouraged to exchange views with our doctors and scientists.

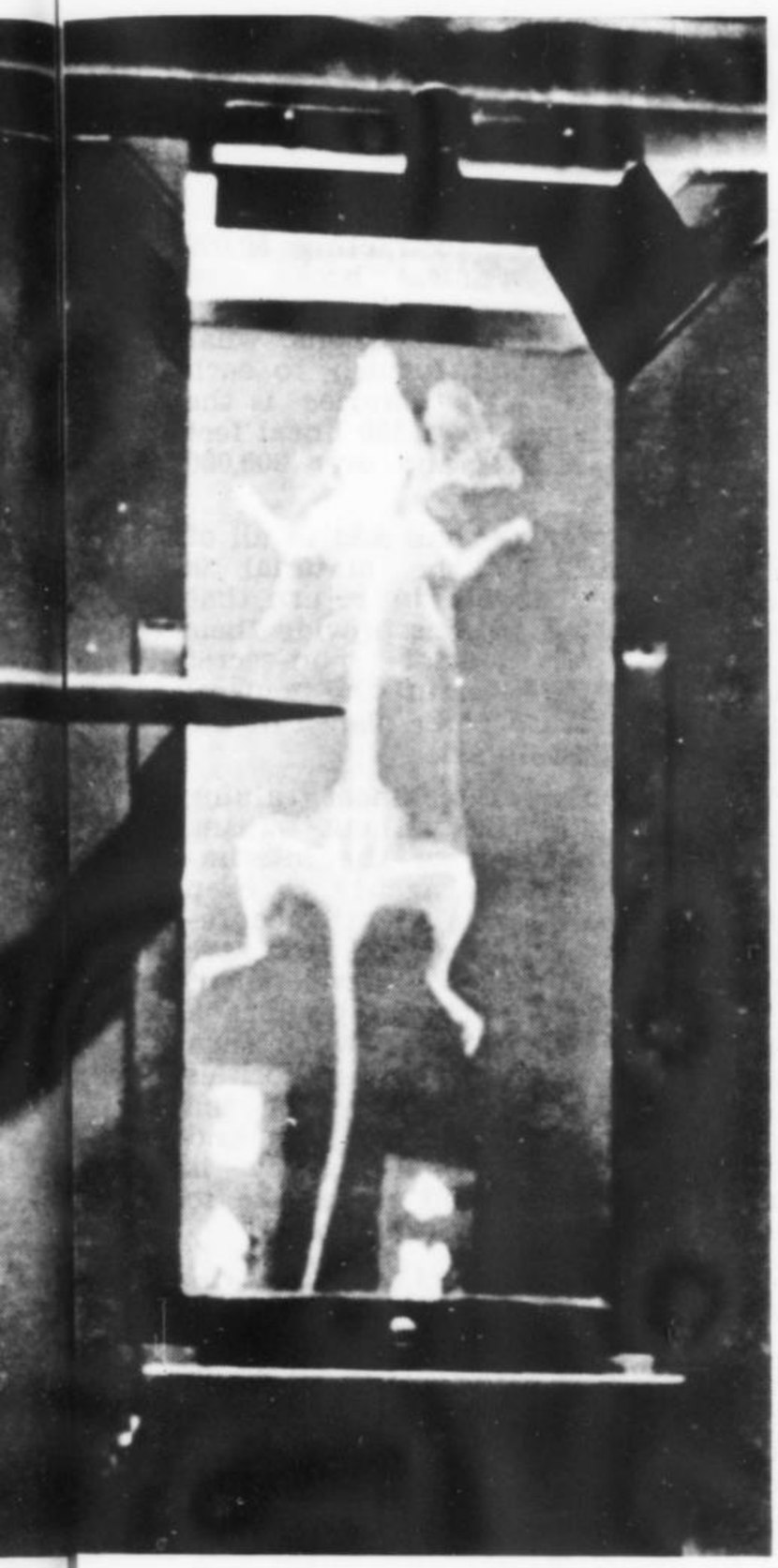
"Fourth and last in our training

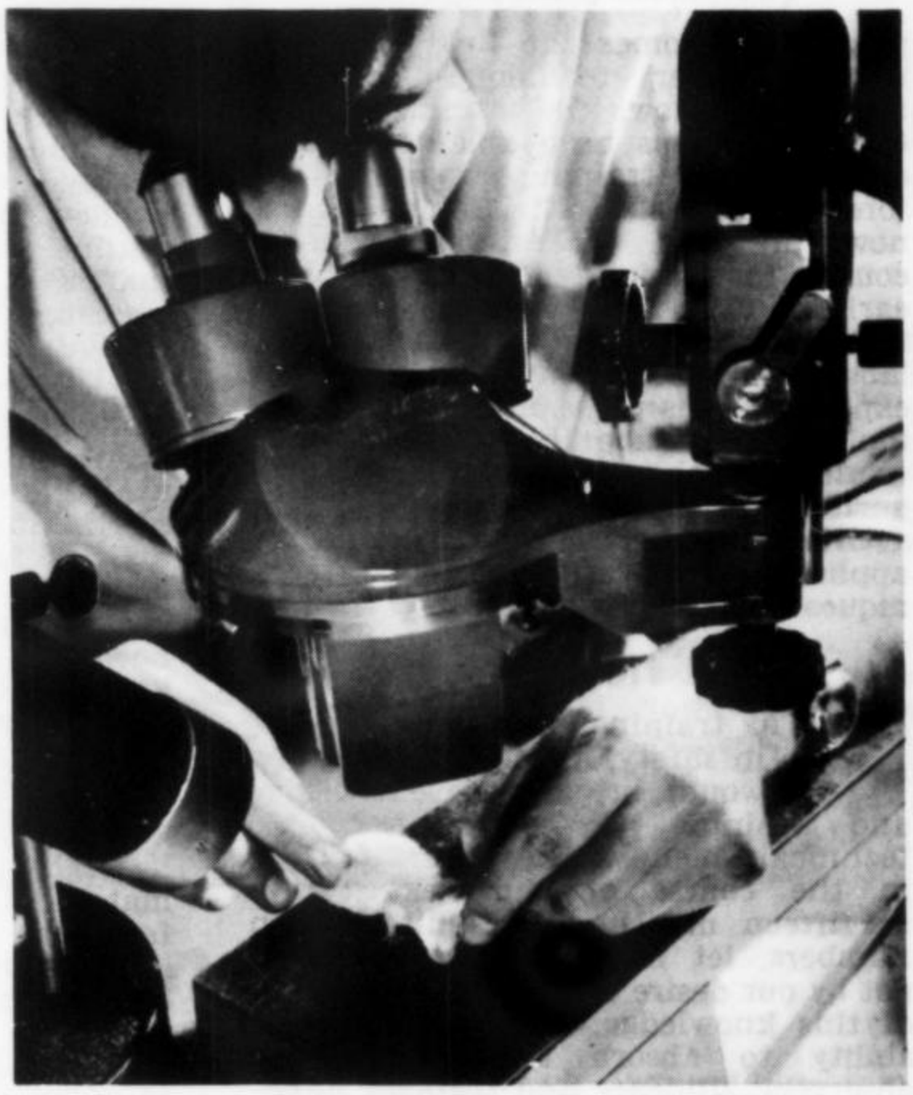
(Cont'd on page 18)



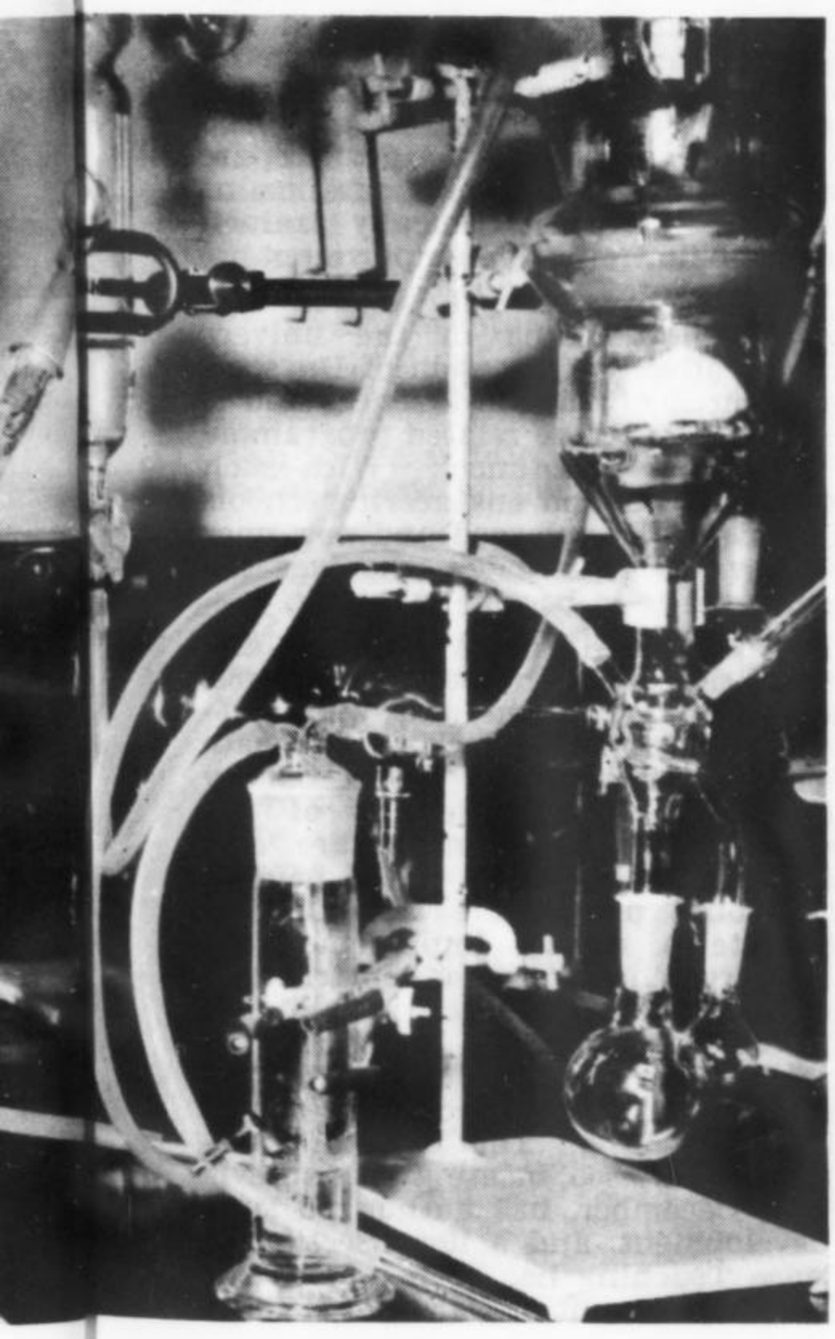


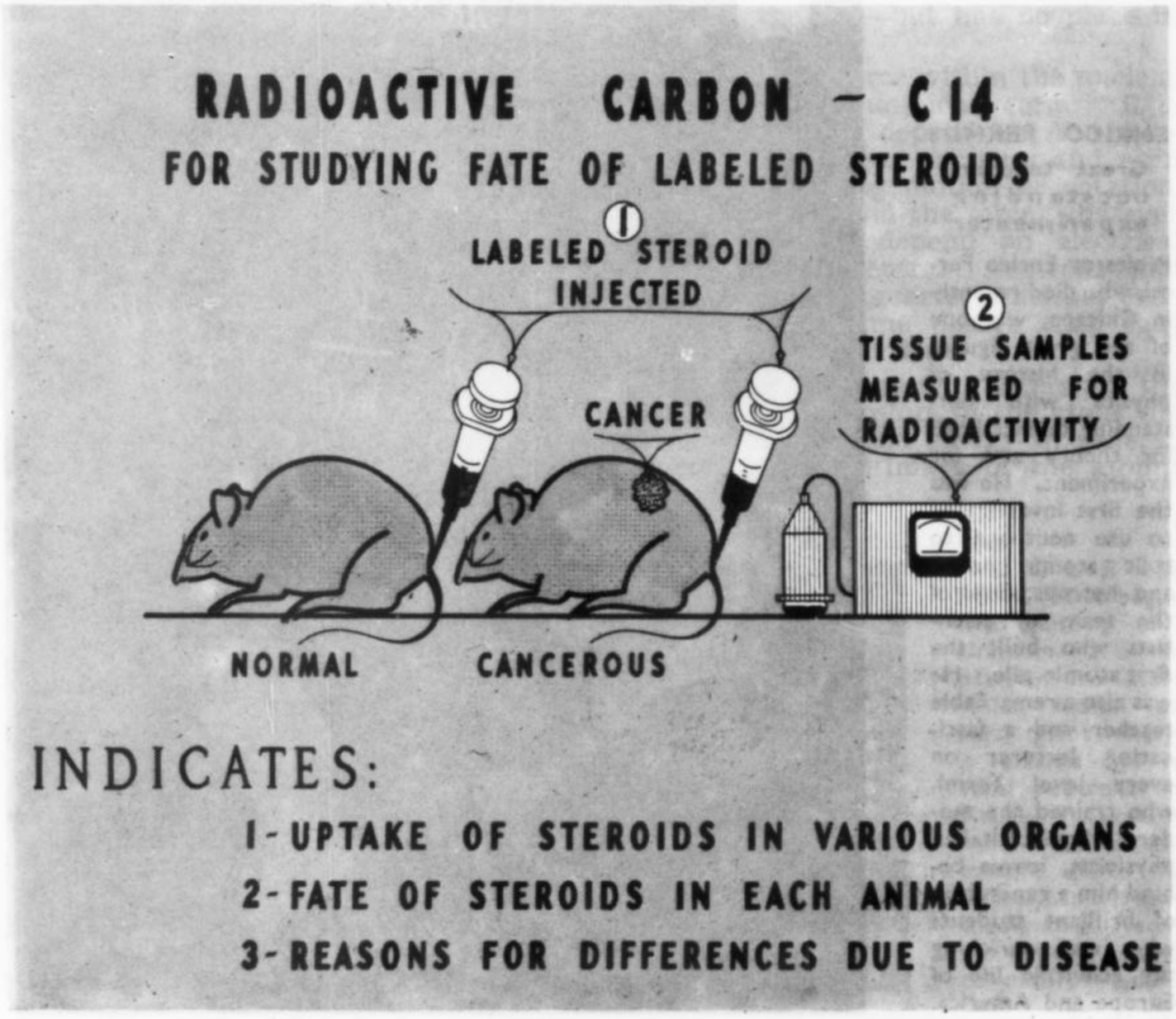
ATOMIC BIOLOGICAL RESEARCH





Recently the United States announced that several of its research centres where atomic energy is used in biology and medicine are to be opened to foreign students. In the vast field of atomic biology and medicine, in which training programmes are being developed today, a vital role is played by radio-isotopes. These are vital elements both in healing and research. Photographs on these pages show examples of atomic biological research whose results will help doctors in all lands to fight disease. In the Division of Biological and Medical Research at the Argonne National Laboratory, U.S.A., an X-ray (above, left) shows a bone cancer located on the second lumbar vertebrae of a mouse. This is part of an experiment to determine the levels of various isotopes that, if absorbed internally in sufficiently large doses, might ultimately produce cancers or other injury. The isotope used here is strontium-90 (a bone seeker). At Brookhaven National Laboratory, U.S.A., students can follow studies of nutrition and disease control (above, right) in which animals are fed or injected with different radio-active elements. These can be traced by the rays given off through the most complex chemical body processes. At the Radium Institute in Paris (below, left) the quantity of radio-active carbon (C 14) in the blood of a living mouse is tested. Tagged (radio-active) rimifon is injected. The experiment is supplemented by an examination of the mouse's excretion. Drawing, below, indicates the different phases of another experimental use of radio-active carbon. (Photos USIS)





A 700,000-page nuclear library

(Continued from page 16)

programme comes the field of radio-isotope tracer techniques. In this field, until now, the Atomic Energy Commission has been able to conduct only a limited training programme for foreign scientists. The Commission is now prepared to establish special courses for foreign technicians to begin early in 1955, these courses to cover a four-week period and to be divided into laboratory work, lectures on laboratory experiments, and seminars on special topics. The laboratory experiments would cover the use of instruments, the purification and separation of radio-active from inert materials, and the application of various isotope techniques to all fields of research.

Vast flow of facts

"THE training courses we propose in safety, medicine and biology would bring basic knowledge and training to more than 250 technical men from other nations in the course of the next twelve to fifteen months—the limitation on numbers, let me add, being imposed not by our desire to restrict the sharing of this knowledge, but simply by our ability to absorb this number of observers, students and trainees effectively and efficiently within our present facilities.

"So much for our early plans for training. Closely allied to this is the question of written information about the atom. We anticipate that from the outset the international agency will carry on a series of information and service activities, obtaining information from the operations of member states in connexion with their own atomic energy programmes and from the agency's own activities. Here is a brief outline of the type of information materials which the United States is prepared to make available in 1955 to the international agency, when set up.

"Contrary to popular belief, the United States has, ever since the beginning of its atomic development, made available through published documents of the Atomic Energy Commission and articles in scientific journals a vast body of research material on the peaceful uses of atomic energy... Up to now, the publication by the United States of documents available to all on the peaceful uses of atomic energy comes to more than 20,000 papers, totalling more than 700,000 pages of data.

"Always mindful of the day when it might be beneficial to present this material in package form, despite the fact that it has always been available in individual items, we have accumulated ten complete libraries of our own material, which we are prepared to give to the principal technical libraries of co-operating nations. And we shall provide more than ten if there is a demand for more. Besides these libraries of our own material, we are prepared to provide complete sets of index cards, and our journals of the past seven years, abstracting 50,000 scientific and technical books and reports published in all countries. Stated in physical dimensions, what we are prepared to furnish to each one of these foreign libraries is the equivalent of more than 300 lineal feet of published reports and over 200,000 index cards.

"Furthermore, we shall add to all of these libraries as the material is published, asking only in return that the co-operating nations provide their collections of official non-secret papers, not available in the general scientific literature, to be placed in the appropriate U.S. libraries."

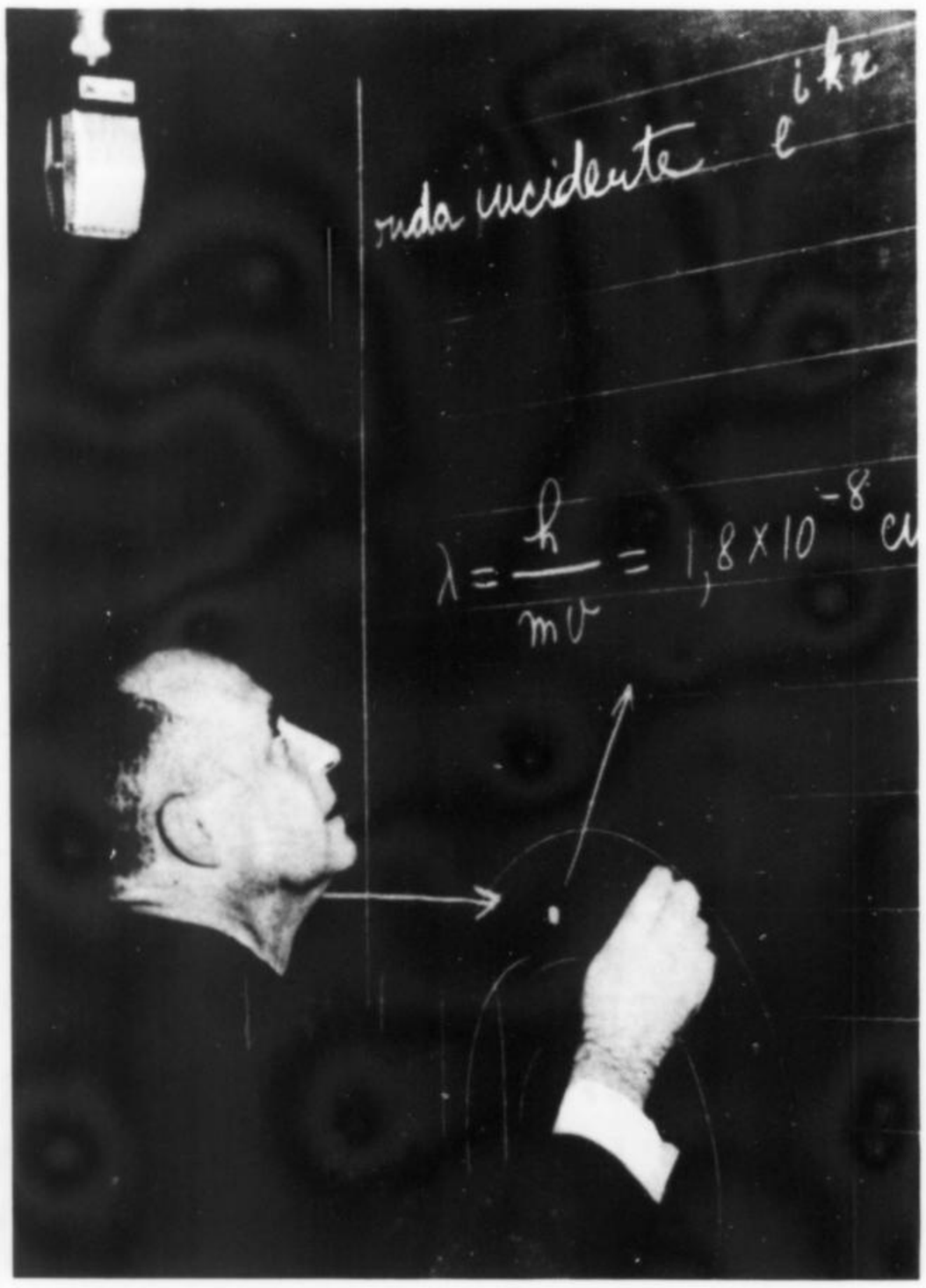
These proposals in technical training are planned for 1955 without waiting for the organization of the international atomic energy agency or even for the United Nations scientific conference. They are designed to save at least a year in the development programme. They should produce a small body of experts who will return to their own countries as authorities ready to take responsibility for the large developments to come. If and when the international agency is organized it may itself undertake to continue this training programme.

Science and the schools

BUT the proposal assumes that competent men with a general background in engineering, science or medicine can be sent from many lands for this specialized training. In the future much larger numbers will be required. This, in turn, means that there must be a rather large increase in the number of men who are trained at home in the fundamental sciences and in the principles and practice of engineering. It means that in many countries both the scientific departments of the universities and the engineering schools will need to prepare for a future in which thousands of scientifically and technically trained men will find effective employment.

The improvement of science and engineering teaching in the universities is already a function of UNESCO's Department of Natural Sciences and is a major item in the related programme of Technical Assistance. With such aid universities and engineering schools will have to be enlarged and new ones will have to be founded wherever the atomic age is to become a reality.

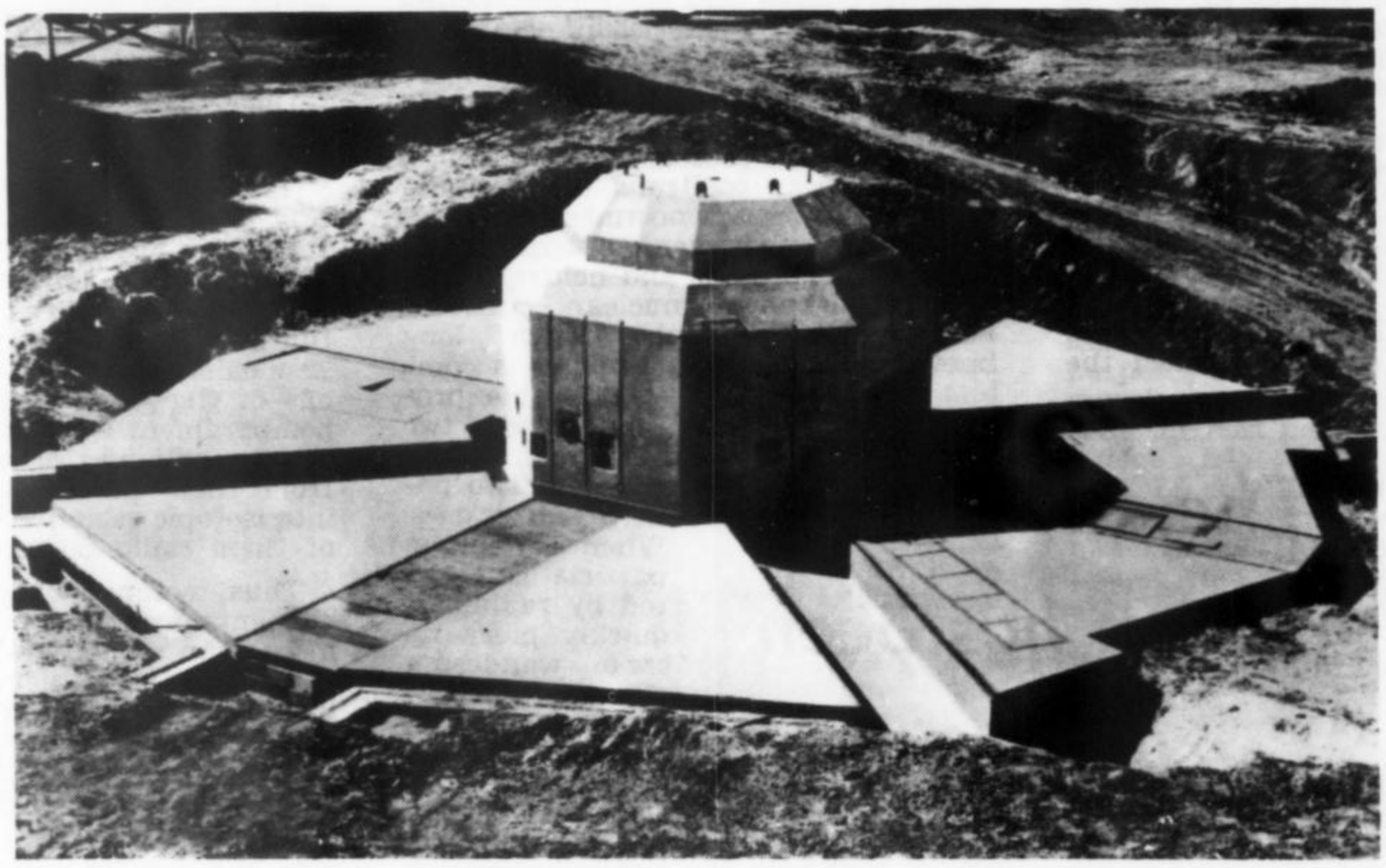
Furthermore, in many countries the universities and engineering schools, though well equipped and well staffed, suffer from the lack of adequate science instruction in the secondary schools. Thus the demands of the atomic energy programmes are certain to reach into the general educational programme also and to stimulate a radical improvement in secondary-school science instruction. Here again, it is the responsibility of Unesco to foresee the need and to extend its services in the improvement and expansion of secondary-school science teaching. The General Conference of Unesco, meeting at Montevideo in December, has authorized such a development and a new Section of Science Teaching has been established in the Department of Natural Sciences.



ENRICO FERMI :
Great teacher, outstanding experimenter

Professor Enrico Fermi, who died recently in Chicago, was one of the great figures in the history of physics with outstanding talents both for theory and for experiment. He was the first investigator to use neutrons to split atomic nuclei and he was one of the team of scientists who built the first atomic pile. He was also a remarkable teacher and a fascinating lecturer on every level. Fermi, who trained the modern school of Italian physicists, leaves behind him a generation of brilliant students who are enriching the scientific life of Europe and America.

NUCLEAR REACTORS



REACTOR FOR RESEARCH which is being built by the North Carolina State College, in the U.S.A. Radiating trenches will carry water, gas and electricity as well as pipes, wires and instrument cables to the reactor. The reactor structure in the centre will house a one-foot diameter spherical core. (Photo USIS).

their design and use

BEFORE we can evaluate the realities of atomic power, as distinct from visions of the future, we need to understand the basic science involved, the installations that generate the power and the factors that enter into their operation. This in turn takes us on an excursion into a realm of science that was not taught in any school even ten years ago. It also brings us into contact with words that hardly existed then but are now becoming familiar in every language.

It is now well known that all matter is composed of atoms, discreet particles that are the smallest and ultimate units of the chemical elements. Until the discovery of radium they were thought to be indestructible and unchangeable. Radium provided the first clues to an atomic interior and its study led eventually to present-day "atom-splitting" in which the atom is laid wide open to fragmentation, to separation of some of its parts and even to the addition of more units and the synthesis of wholly new atoms.

The process of splitting is now known by the more accurate term, "fission", and those types of atoms which undergo fission with relative ease, as in the atomic bomb, are known as "fissionable" or "fissile". It is pity that, in the English language at least, there is as yet no verb to express the action of fission. "To fiss" is almost unthinkable and "to fissure" does not quite convey the meaning but can hardly be improved upon.

The complex installation in which fission takes place with the release of energy and the production of new elements from the fissile material was known originally as a "pile" because it was in fact a pile of uranium rods and blocks of graphite. It is more properly called a "reactor". In common speech it is the atomic furnace where the energy is generated from the atomic fuel, though there is no fire and no combustion in the usual sense.

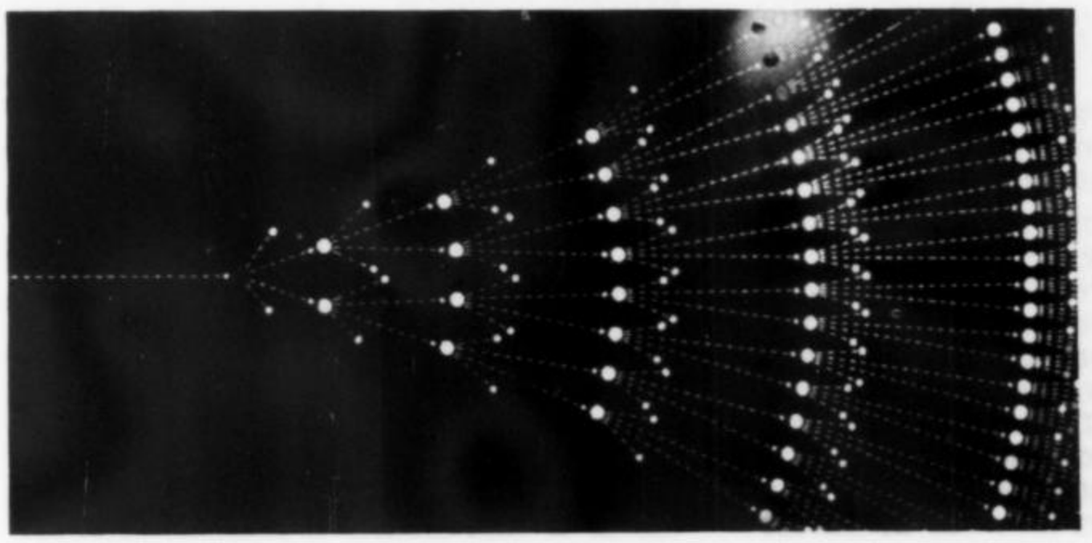
The new science is one of events within the atom but more especially within the nucleus of the atom. It is unfortunate that the terms "atomic energy" and "atomic power" have become popular, for in truth "nuclear energy" and "nuclear power" are more correct. The world within the atom, as revealed by the natural rays from radium and by cosmic rays, is almost incredible from the ordinary human point of view. This is not merely because it is so complex but also because the basic particles within the nucleus have new and odd relations to both matter and energy that do not fit into our common conceptions.

The nucleus of the atom contains all the "matter", yet is so small that it occupies only a thousandth of a millionth of a millionth of the space within the atom. It occupies a relatively smaller space within the whole atom than the sun occupies in the whole great solar system. In that case its density (that is, its weight per cubic inch) must be a thousand times a million times a million times that of ordinary materials. Whatever that atomic core is made of, it is so dense that a lump of it as large as a drop of water would weigh two million tons.

But that is only half of the astonishing situation. Energy is similarly concentrated there. Within that exceedingly minute volume of the atomic nucleus there are new forces that hold the mass together. The earth itself is held together by gravity but the force within the nucleus must be so much stronger than gravity that there is no word to express it. The force of gravity would have to be multiplied by a number that comprises the figure 1 followed by 37 zeros. Gravity holds the planets in their courses and the stars in the sky—but has no place in the nucleus.

The binding force within the nucleus is of a new and unknown form. It is complicated and depends on the velocity of the nuclear particles and even on their spinning motion or rotation. On the other hand the force, whatever it is, does not depend on electrical charges, for (neutral) neutrons and (positive) protons seem to attract each other to the same degree that they attract their own kind.

This is the present mystery of the nucleus and therefore of the atom and thus of matter and energy in general. There, in the intimacy of the atomic



NUCLEAR REACTION begins with splitting of a Uranium 235 or plutonium atom. When fission occurs, great energy is released and several neutrons are ejected. These strike other U-235 or plutonium atoms like bullets and fission them, thus freeing more energy and more neutron bullets.

The sources of atomic energy

nucleus, lies the secret of the true nature of matter, of energy, and of their relation to each other. It is the purpose of the great cyclotrons and synchrotrons, such as those now being built at Geneva for the European Organization for Nuclear Research, to study this nuclear world. (See page 23.)

It is the nucleus that explodes during fission, that emits rays in radio-activity, and that combines with other nuclei to generate the sun's heat. It is the nucleus that will provide the energy for what we have called the atomic age. It is by the exploration and partial mastery of the nucleus that science has in recent years been able to duplicate and greatly improve on the radio-activity of radium, for instance, and has surpassed the dream of medieval alchemists by changing one chemical element into another, such as changing gold into mercury or producing explosive plutonium from harmless uranium.

The alchemists' dream has been surpassed

Just as the atoms of the various chemical elements combine with others to form the molecules of chemical compounds, so a number of still smaller particles combine to form the different atomic nuclei. Three such primary particles must be mentioned briefly: the proton, the neutron and the electron, the last being the familiar "particle of electricity" that flows through wires in countless millions to form an electric current. It has a charge—or perhaps one should say it is a charge—of negative electricity, which is to say that all electricity is negative (and thus misnamed).

Less familiar is the proton. It is almost 2,000 times heavier than the electron. It is definitely matter rather than electricity. Indeed it is for some reason positively charged, as if it had itself lost a negative electron. It is an essential component of all atomic nuclei, combined and compressed in them into firm union. But it has a comfortable existence all its own as the entire nucleus of the hydrogen atom, the simplest and lightest atom.

At the surface of the hydrogen atom is a single electron, vibrant and dancing in a complex mathematical orbit. That electron is responsible for the atom's chemical properties and enables it to combine with other atoms to form molecules, such as with oxygen to form water. But at the centre of the hydrogen atom is its concentrated mass, its nucleus, the single proton whose positive charge balances that of the relatively distant electron, making the whole atom electrically neutral.

Every other atomic nucleus is more complex and heavier than that of hydrogen and every one contains neutrons in addition to its protons. The neutron is practically identical with the proton, with almost exactly the same weight, but it has no positive charge and so is electrically neutral. When neutrons form a part of an atomic nucleus they add to its mass and weight but do not affect its positive charge and therefore do not change the number of external electrons that are responsible for the atom's chemical properties.

These are the essential components of all nuclei: protons, neutrons and electrons, plus positrons, mesons and others that need no mention here. There are, however, several combinations of protons and neutrons that form well-known nuclear particles. For instance, the "alpha particle", long known as emitted by radium, is composed of two protons and two neutrons, and thus has two positive charges. When the alpha particle is emitted by radium it quickly picks up two wandering electrons and becomes an atom of helium, for the alpha particle is identical with the helium nucleus and two external, circulating electrons make it a neutral whole atom.

Another such stable group comprises a single proton and a single neutron, and thus has a single positive charge. This group takes part in many nuclear reactions and is called a deuteron. When it picks up a single electron in an external orbit it forms an atom that is identical with hydrogen in its chemical properties though it is twice as heavy because its nucleus is not merely a proton but has a neutron added. Deuterium is therefore an "isotope" of hydrogen that is called "heavy hydrogen". Two deuterium atoms combine chemically with one atom of oxygen to produce "heavy water".

Hydrogen, with only one proton, is the simplest and lightest atom. But there are 92 different chemical elements and the atomic nuclei of all the others are made up of larger numbers of both protons and neutrons. The heaviest and most complex of all the common atoms is uranium, whose nucleus contains 92 protons and 146 neutrons, a total of 238.

But this is not the only type of uranium that can exist and therefore not the only possible composition of the nucleus.

Swift neutrons explode the adjoining atoms

There are other forms with 141 neutrons, or 143, or 147. They all have 92 protons and thus all of them have identical chemical properties. But the weight of the atom is the sum of the weights of the protons and neutrons, so that these three varieties of uranium have atomic weights of 233, 235 and 239, respectively.

Such varieties of atoms of the same elements, all with the same chemical properties but with different weights and a differing number of neutrons, are known as isotopes. Most of them seem to be under some sort of strain and undergo a disintegration during which they emit particles and rays of various sorts. Thus they are radio-active and are known as radio-isotopes. Their rays are useful and will be discussed in a subsequent article of this series. (See page 29.)

Isotopes of the naturally radio-active elements have long been known, primarily because of their distinctive rays. But bombardment of almost any of the 92 elements by high-speed protons in one of the great modern cyclotrons or bombardment by neutrons in an atomic reactor will add or subtract neutrons from their nuclei and convert them into isotopic varieties, some stable, most of them radio-active.

Thus isotopes of all the chemical elements are now known—a total of more than a thousand different atomic varieties. In fact neutrons and protons have been added to uranium in various stages so that six new, previously unknown elements have now been created, the last of them—up to now—being No. 98, Californium.

In the case of uranium that variety known as uranium 235 (from the weight of its atom) spontaneously disintegrates when struck by a stray neutron, coming perhaps from outer space as a cosmic ray, and ejects some of its neutrons. When such a neutron strikes an atom of uranium 238 it is captured to form uranium 239. This in turn instantly goes through a more complicated nuclear reaction and forms plutonium, with a weight of 240.

When that atom is struck by a neutron perhaps from another atom of uranium 235, it is literally split in two. Smaller atoms of lighter elements result but the important thing is that when this happens some of the binding energy within the plutonium nucleus is released and the atom not only splits but the fragments fly apart with tremendous energy. This reaction is the basis both of the atomic bomb and of atomic or nuclear power.

In the bomb the explosion of one atom releases swift neutrons which at once explode adjoining atoms, and the neutrons from them in turn explode still other atoms. Within a millionth of a second the entire mass disintegrates in the indescribable explosion that has horrified the world. But when this disintegration is controlled so that it proceeds at a manageable rate, then the energy of disintegration may be liberated over the course of hours, months or years. Precisely the same energy that feeds the bomb feeds the atomic furnace, the "nuclear reactor".

The reactor is thus the scene of controlled nuclear explosions. In it, the high-speed nuclear fragments, and neutrons too, are slowed down, their energy is absorbed in the surrounding materials and reappears as heat. It may be that by future research the

high-speed nuclear projectiles can be harnessed to generate electricity directly but for the present all atomic reactors generate heat and their energy can be used only in that form.

But if reactors are to be used for industrial power this heat must be captured and put to work. Modern reactor design is largely a problem of how to capture a maximum quantity of heat and thus to utilize the energy of the exploding atoms efficiently. The crucial point in present atomic power development is precisely that: whether or not enough heat can be captured to justify the enormous cost of the reactor and of the fissionable uranium and whether or not the power produced will compare in cost with the power made by the combustion of coal or any of the other fuels.

Three million times the heat of coal

The task is complicated by the fact that neutrons are emitted during fission at very high speed, which are dangerous to personnel, ruinous to equipment and, in addition, convert many of the atoms that they strike into radio-active isotopes which are themselves dangerous. Consequently, the heat cannot be removed from the reactor by any simple device. The cooling liquid that flows through the reactor becomes radio-active and cannot be used directly to operate an engine.

In one common type of reactor the coolant is liquid metallic sodium. This flows from the reactor through pipes to a heat-exchanger where it is in turn cooled by water before it returns to cool the reactor once more. In that exchange the water turns to steam that is not dangerous because the radio-active sodium does not emit neutrons and thus does not affect the water or the steam. The latter can then be passed through a steam turbine where its high-pressure energy spins the turbine and thereby generates electricity. Thus by successive steps the energy which came from the exploding plutonium or uranium atoms emerges from the power house as electric current and is in no way different from a current generated by other methods.

It is apparent then that the nuclear reactor is merely the source of energy and in a large power house would replace only the coal furnace; all the remaining parts of the power installation would be unchanged.

There are many types of nuclear reactors. They all have features in common that differ only in degree. The fuel is always a fissionable material, either uranium-233, 235 or plutonium. Each of these releases almost three million times as much heat when it disintegrates as does the combustion of an equal weight of coal.

The pure fissionable materials are, however, extremely difficult and costly to produce. Uranium-235 is present in all natural uranium but comprises only 0.7 % of it. Since it is chemically identical with the 99.3 % of uranium-238, it can be separated from it only by complex and costly physical methods. Plutonium must be made from uranium-238 in a reactor and uranium-233 can be similarly made from thorium. The pure fissionable fuels therefore cost many thousands of dollars per pound. For the generation of power they are commonly used in a less pure form in which ordinary uranium is merely "enriched" with the fissionable varieties.

If the purpose of the reactor is to produce plutonium, high grade uranium-235 is the fuel. It converts ordinary uranium-238 into plutonium which can then be chemically separated in the pure form and used in the bomb or as the fuel in another reactor. If the purpose of the reactor is to test the resistance to neutrons of metals and other materials that are to be used in the reactors or in atomic engines, the fuel may again be a pure fissionable uranium in order to get a maximum concentration of neutrons acting upon the materials being tested. If power alone is the purpose of the reactor the fuel is "enriched" uranium because a high intensity of neutrons is not needed and a slower reaction is more likely to generate usable heat.

Every reactor also has some form of "moderator", a material like graphite, heavy water or beryllium, which serve primarily to slow down the neutrons from their original speed of many thousands of miles per second to a speed at which they are more likely to be captured by the uranium atoms and thus to cause fission.

Every reactor also needs a material which actively captures neutrons but is not capable of fission by them. The commonest material for this purpose is the metal cadmium. It reduces the number of flying neutrons and thus reduces the rate of the fission reaction. The cadmium is commonly used in the form of thick rods which can be inserted into the reactor if the reaction is going too fast and thus slow it down. They may, in fact, be inserted fully, whereupon they stop the reaction completely and shut down the reactor. Thus the speed of both the fission reaction and of the power generation is then controlled and danger of a runaway reaction or an explosion is avoided.

The furnace which breeds its own fuel

Also every reactor must be provided with means for carrying away the heat. While this is necessary for all reactors to keep them from melting, the cooling liquid is the crucial part of a reactor that is used for generating power, as has been said.

Finally, every reactor must also have an effective shield to absorb neutrons that escape from the fission reaction and prevent them from penetrating into the room where scientists and attendants are at work. Such shields are usually heavy walls of lead or concrete, or both. No reactor can safely operate without a shield and it is for this reason that there is no hope that atomic reactors can ever be used for the propulsion of automobiles or for the heating of homes. The shield alone must weigh many tons. While this is no obstacle to its use in a large power station or in a marine vessel, it is one of the severe limitations on the use of any atomic engine for airplanes.

Until May of 1953 the prospect of using atomic fuels and reactors as a major source of industrial power was a bright hope but not more than that. There were two major obstacles. One was the cost of the pure fissionable fuel, which has never been stated, since it is made only by governments for military purposes and it cannot now be bought anywhere. It was nevertheless certain that the cost per pound was very high indeed. The second obstacle was the lack of any certainty that there is enough uranium available in the minerals of the world to supply an atomic industrial age. Both obstacles were eliminated by the announcement of the success of the experimental "breeder" reactor, operated by the U.S. Atomic Energy Commission at Arco, Idaho, since 1951. At one stroke the effective supply of uranium was multiplied by 140 and the effective cost of the fuel was reduced almost to zero. The breeder reactor is a major item in the prospect of atomic power.

Briefly it is a reactor that generates power and at the same time produces as much new fissionable material as it uses up, and probably more. This at first thought seems as impossible as would a coal furnace that consumes tons of fuel to generate heat but at the end contains more fresh coal than was fed into it. Such a furnace would operate without any fuel cost and, in fact, could sell new coal to other users. In the case of coal it is, of course, impossible. But with atomic fuels in a breeder reactor it is only one of many apparent miracles.

When an atom of uranium-235 fissures it emits high-speed neutrons, as has been said. If the fission reaction is maintained, one of the neutrons must strike another atom of uranium-235 so that this, in turn, will undergo fission. If two neutrons are emitted the second may do the same, but if ordinary uranium-238 (which does not fissure) is also present the second neutron may strike it, and thus change it into plutonium. Plutonium is fissionable, exactly as is uranium-235, and the original value of the fuel has thus been restored. If the uranium-235 fission always emits two neutrons and if both processes are 100 % efficient, the furnace would be continuously manufacturing its own fuel out of the cheap natural uranium-238. The practical questions then are: How many neutrons does uranium-235 emit on fission and how efficient is the process?

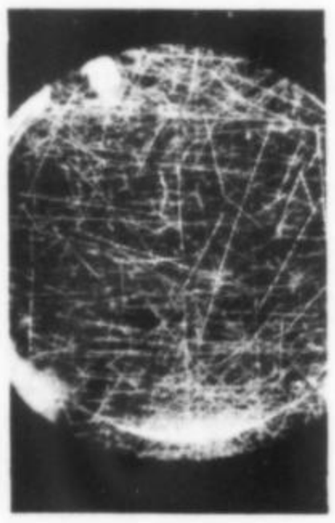
The exact number of neutrons emitted has never been revealed. It has, however, been annouced that there are "more than two". The margin this gives is such that some neutrons may be lost by striking the rods or other inert materials in the reactor and yet leave one

THE COST OF FUEL WILL BE NEGLIGIBLE

to carry on the reaction and one to make new fuel. If three neutrons are emitted there is ample margin and it thus becomes possible that the reactor may even make more fuel than it uses.

That this is possible is still a real hope, though it has as yet no official confirmation. What the U.S. Atomic Energy Commission did announce in May 1953 was that fissionable plutonium is produced in the breeder reactor "at a rate that is at least equal to the rate at which the uranium-235 is being consumed".

In the case of thorium, however, it is known that more fuel can be produced than is used. The original fuel in this case is also uranium-235. If a neutron from it strikes an atom of thorium-232 (which is not fissionable) that atom is converted into fissionable uranium-233.



The reaction is efficient enough so that more uranium-233 is produced than the uranium-235. When more fuel is produced than consumed, the excess can be sold to other users, presumably the Government itself, and the returns would reduce the net cost of power which has been produced in the nuclear reactor.

In both cases common and relatively cheap materials, uranium and thorium, are converted into atomic fuels by the reactor whose primary purpose is the economic generation of power. This means that all the uranium and thorium in the world could be converted into effective fuels instead of only the 0.7 % or 1/140th of the uranium that is present as uranium-235. This multiplies the world's resources of uranium fuel 140 times. What is more, it adds all the great deposits of thorium to the fuel supply.

The breeder reactor which has supplied this information and created this confidence is a relatively small one with a production of 250 kilowatts of electricity—enough for only a small town. At its centre is the core of fissionable uranium-235, about the size of a football. Around this core is a thick cylinder of ordinary uranium-238 which catches the neutrons to form plutonium. The heat evolved is equivalent to 4,000 watts for every cubic inch of the active core.

In comparison, an oil-fired boiler, such as is used in battleships, gives only 600 watts per cubic inch of fuel. The heat from the breeder reactor is conducted away by a flow of liquid sodium through inserted pipes. The sodium stream emerges from the reactor at a temperature of about 660° F and delivers its heat to water in a heat-exchanger and thus forms steam to drive a turbine.

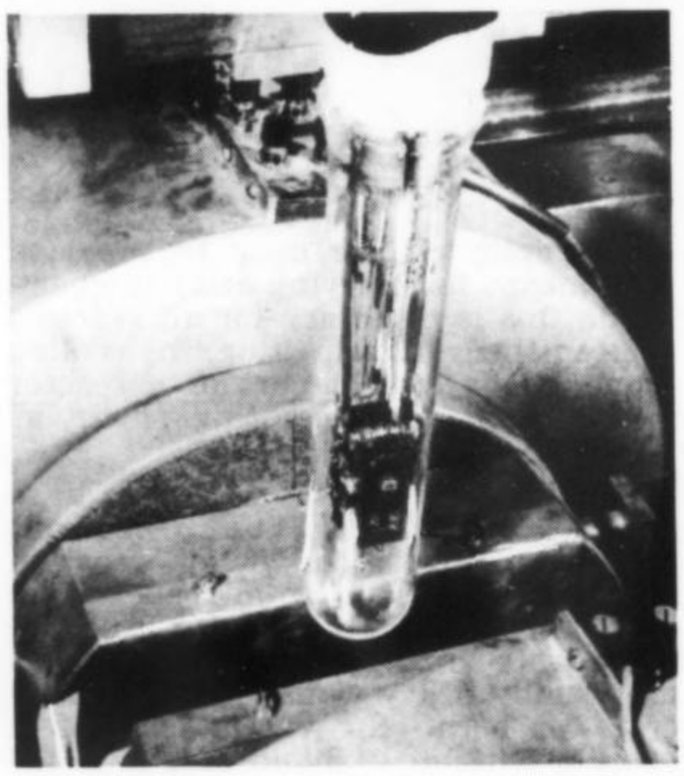
COSMOTRON, at Brookhaven National Laboratory U.S.A., is the second most powerful of giant machines used by scientists to bombard atomic nuclei with high energy particles and thus learn more about their make-up and nature. (Most powerful machine operating at present is the Berkeley Bevatron, at the University of California.) The huge "doughnut-shaped" magnet, 75 feet in diameter, guides the particles in a circular path while a succession of electric boosts gives them phenomenal speeds. Collisions between high-energy particles and nuclei are seen as thin white tracks (photo, left), when photographed in an instrument called a cloud chamber.

To calculate the cost of the fuel used in producing power is easy enough. As has been explained, this is now not the cost of the expensive, fissionable uranium-235 but of ordinary uranium-238 the price of which is approximately $35 a pound. Since 20 pounds of uranium will produce some 52 million kilowatts hour of electricity—enough to light a fairly large city for a year—the cost of the fuel used would be only 0.0013 cents per kilowatt hour. Since the usual price of electricity is more than one cent per kilowatt hour, the fuel cost itself is quite negligible.

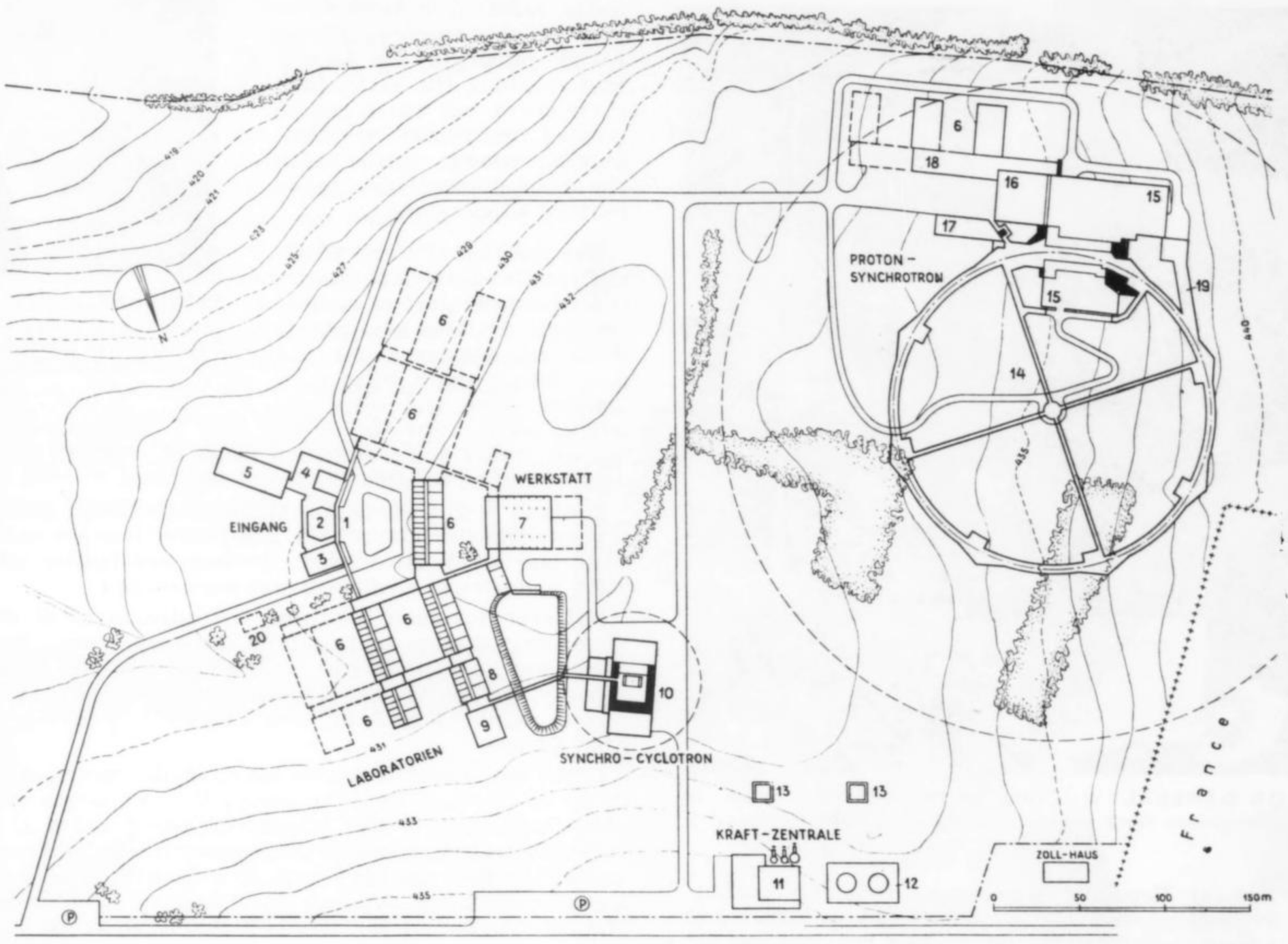
But such a calculation is illusory because other expenses are involved. The most important of which is the occasional removal of the covering cylinder of natural uranium and its chemical processing to extract the plutonium for the future fuel. This is a difficult operation because the very strong radio-activity of the materials makes it necessary to conduct the chemical operation by remote control, without contact with personnel. Furthermore, the core itself gradually becomes exhausted as the fission products accumulate in it. It too must therefore ultimately be removed so that the remaining uranium-235 can be extracted from the variety of other and smaller radio-active atoms that are the products of fission. The processing of the fuels therefore adds an item of cost which is at least ten times that of the original uranium. In that case the fuel cost is 0.013 cents per kilowatt hour, which is still negligible.

But there are other costs. The highly radio-active products must be disposed of. Some of them are valuable for use as radio-isotopes. Most of them are of no value but are intensely radio-active and are therefore a serious hazard. In any case the cost of disposing of radio-active wastes is an important one.

But the major cost is the building of the reactor itself which is between 2 million and 20 million dollars, or even more. The calculation of the practical, final cost of electricity must therefore be postponed to a more comprehensive discussion of other reactor installations and the plans of electrical power companies in a subsequent article (page 41).



OMEGATRON, a miniature machine for research with high energy particles, developed by the National Bureau of Standards, Washington. The heart of the instrument, enclosed in a glass tube, is little larger than a packet of cigarettes, but for experimental purposes it is mcu ıted between the bulky pole pieces of an extremely powerful electro-magnet. The omegatron makes possible for the first time, the exact evaluation of the Faraday, a unit of quantity of electricity. Its other uses include measurement of the mass of nuclear particles and analysis of gases and vapours. Here the omegatron is being lowered between the magnet poles, (Photo USIS).



AN INTERNATIONAL CENTRE for carrying out nuclear research is being built near Geneva. This plan shows layout of the centre which will house the world's most powerful instruments to explore matter and energy. One machine will generate particles which approach the speed of light. Numbers on plan indicate : (1) entrance, (2) lecture room, (3) library, (4) restaurant, (5) laboratories for theoretical work, (6) experimental laboratories, (7) central workshop, (8) workshop for synchro-cyclotron, (9) synchro-cyclotron control room, (10) synchro-cyclotron (a high energy accelerator), (11) power station, (12) fuel tanks, (13) cooling towers, (14) circular magnet for proton-synchrotron (this giant magnet will be buried in a concrete filled trench), (15) experimental halls, (16) proton-synchrotron workshop, (17) generators, (18) laboratories for theoretical work, (19) linear accelerator (machine for accelerating nuclear particles).

CERN WHERE GIANT FORCES WILL PENETRATE A TINY WORLD

At the end of the last century, great scientists, often working alone and under difficult conditions, discovered radio-activity, radium and the X-ray, but none of them considered that the atom had an interior. Today scientists delve within the atomic nucleus and study a maze of fundamental particles of matter and of energy inside—electrons and positrons, protons and neutrons, mesons and neutrinos.

But today, the frontiers of atomic science are so far from the everyday world that it takes large, expensive and highly organized expeditions to reach them. A large cyclotron for penetrating the nucleus of the atom costs millions of dollars. To operate it costs thousands of dollars per day and requires the combined work of large teams of physicists, chemists, mathematicians, engineers, and electricians, and also biologists and physicians.

The work, in fact, is so expensive that no university can establish a modern fully-equipped laboratory without help from its government. And for that matter, very few governments can afford to finance a major nuclear research programme by themselves. The only solution is international collaboration.

Unesco has been concerned with this problem since 1950 when it was asked to help bring together European scientists and governments to establish a European centre for nuclear research. A few months ago this project became a reality when the European Organization for Nuclear Research came into being following the ratification of an international convention by nine countries.

CERN, as the Organization is usually called (from the French title—*Conseil Européen pour la recherche nucléaire* —of the temporary body which preceded it) is the first international organization for scientific research set up by an intergovernmental Convention. Today this Convention has been ratified by ten countries: Belgium, Denmark, France,

EUROPE'S NUCLEAR EXPLORERS

DIRECTOR-GENERAL of CERN is Professor Felix Bloch, of Switzerland. Professor Bloch was winner of the 1952 Nobel Physics Prize.

German Federal Republic, Greece, Netherlands, Norway, Sweden, Switzerland and the United Kingdom. Italy and Yugoslavia have also signed the Convention but have not yet ratified it.

CERN is not concerned with atomic energy, but only with basic research on the structure of the atomic nucleus. The part played by Unesco in its establishment offers a good example of the way the Organization can help to develop international co-operation in the field of scientific research.

M. Henri Longchambon, Secretary of State at the French Department of Scientific and Technical Research, recently said that while technicians now know how to produce atomic energy, the mechanism and behaviour of nuclear forces are still shrouded in mystery. In investigating these phenomena, research is focussed on very high-energy particles, found principally in cosmic rays reaching the earth from outer space, but which can be created artificially by bombarding atomic nuclei with the help of machines called particle accelerators.

PRESIDENT of CERN is Sir Ben Lockspeiser, Director, Department of Scientific and Industrial Research, Great Britain.

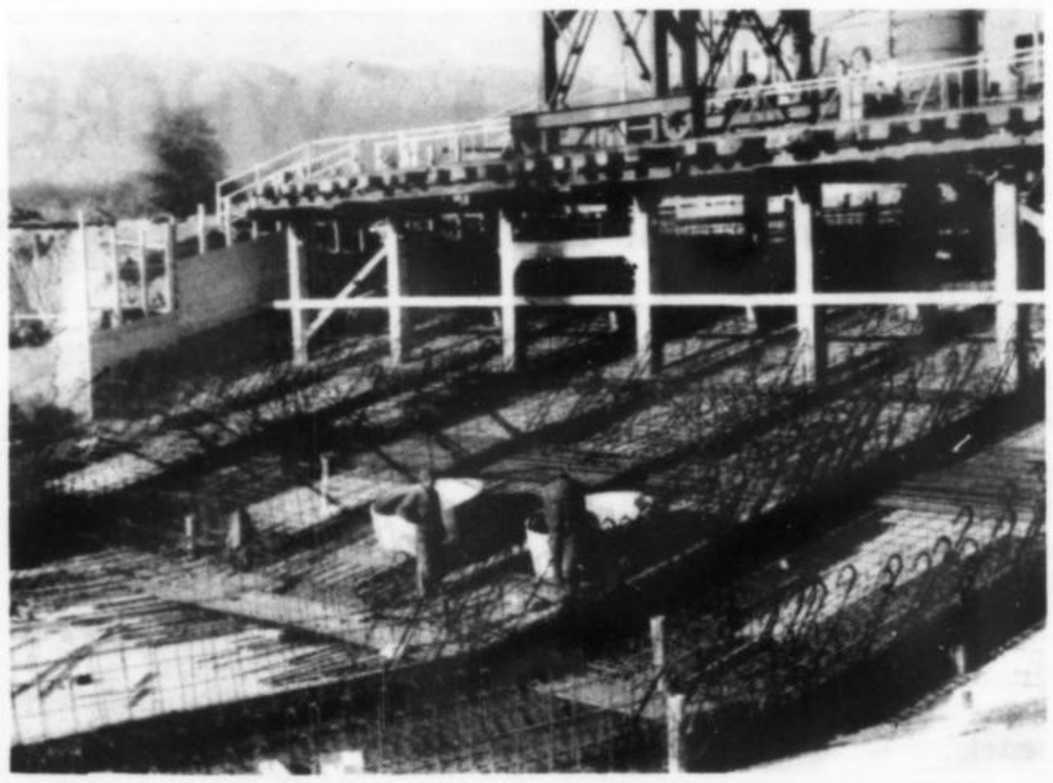
The creation of these artificial cosmic rays in laboratories is an essential part of nuclear research. That is why physicists and engineers, for the past twenty years, have been building more and more powerful accelerators. In Europe only a few countries have enough money and a sufficient range of scientific and technical resources to build their own machines.

England, with a thousand-million electron-volt accelerator, is very advanced in this field, and France has just decided to build one which is to reach 2.4 thousand-million electron-volts, and several medium-power accelerators.

But even for such countries, the advantages of international co-operation in this field are very great. Even the most modern American institutions, which were still, quite recently, leading in this field, entrust such research to specialists recruited from all over the world, and particularly from Europe.

CERN has therefore set up teams of the foremost specialits in its Member States to design the two accelerators : a 600 million electron-volt synchro-cyclotron and a 25 thousand-million electron-volt proton-synchrotron. The construction of the first machine—one of a classical type—raises no special difficulties and can be completed in 2 or 3 years. The construction of the second machine, however, is a daring venture. It is to have five times the power of the most powerful accelerator at present operating in the USA (the Berkeley Bevatron) and is to be built on an entirely new principle. The speed of the particles it generates will approach the velocity of light—the absolute ceiling. It will take six or seven years to build.

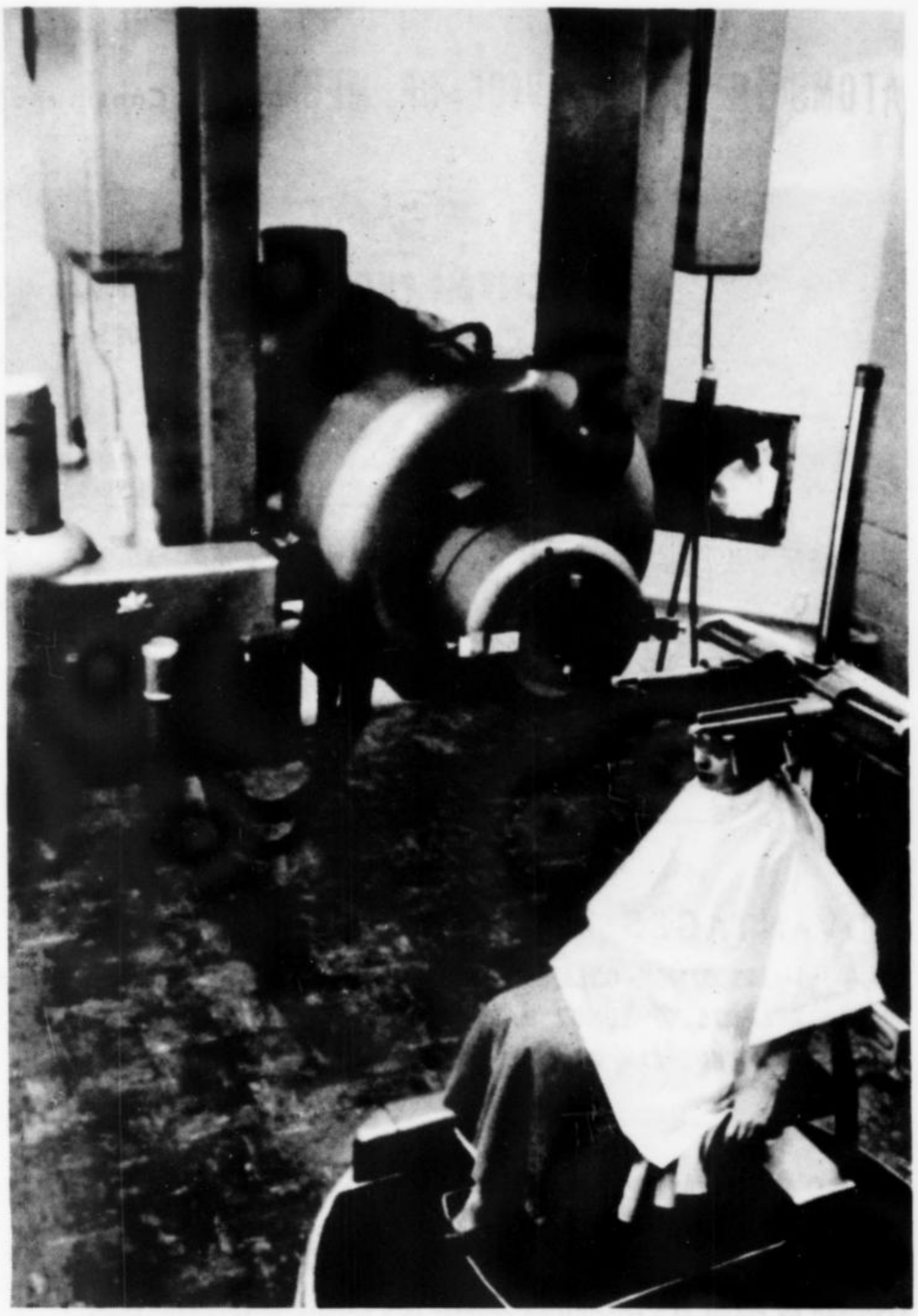
There will be nothing secret about CERN's work. Its creators hope that it will mark the beginning of a new era of international collaboration in atomic research. Its elaborate and costly equipment will serve all science and through it a world that is anxious to make good use of the secrets of the atom.

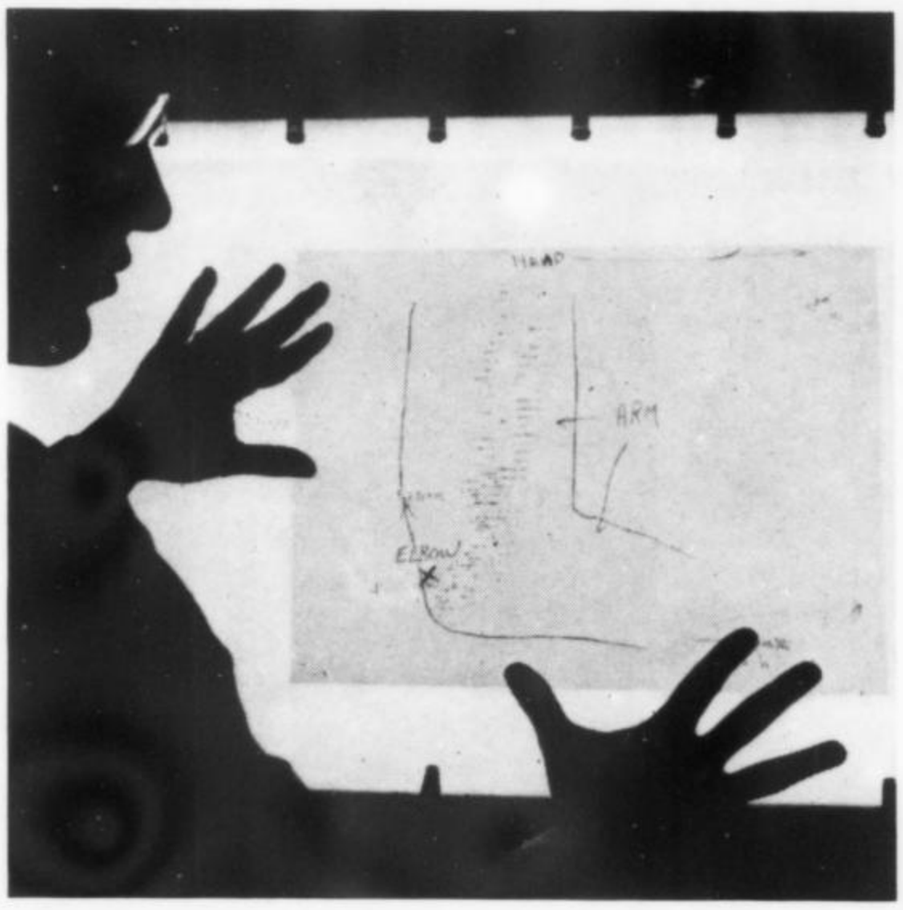


CONSTRUCTION of CERN'S central laboratory is now going ahead on a site some 2,000 feet square about three miles northwest of Geneva, Switzerland, and adjoining the French border on land offered by the Geneva Canton. The cost is estimated at 120 million Swiss francs (28 million dollars) for the first seven years, including construction and operation. Project was first proposed by the European Cultural Conference in 1949 and adopted by the Unesco General Conference in 1950. In 1953, a Convention establishing the Organization was signed in Paris. CERN became a reality on September 29, 1954, when the Convention had been ratified by nine of the twelve nations which have signed it.

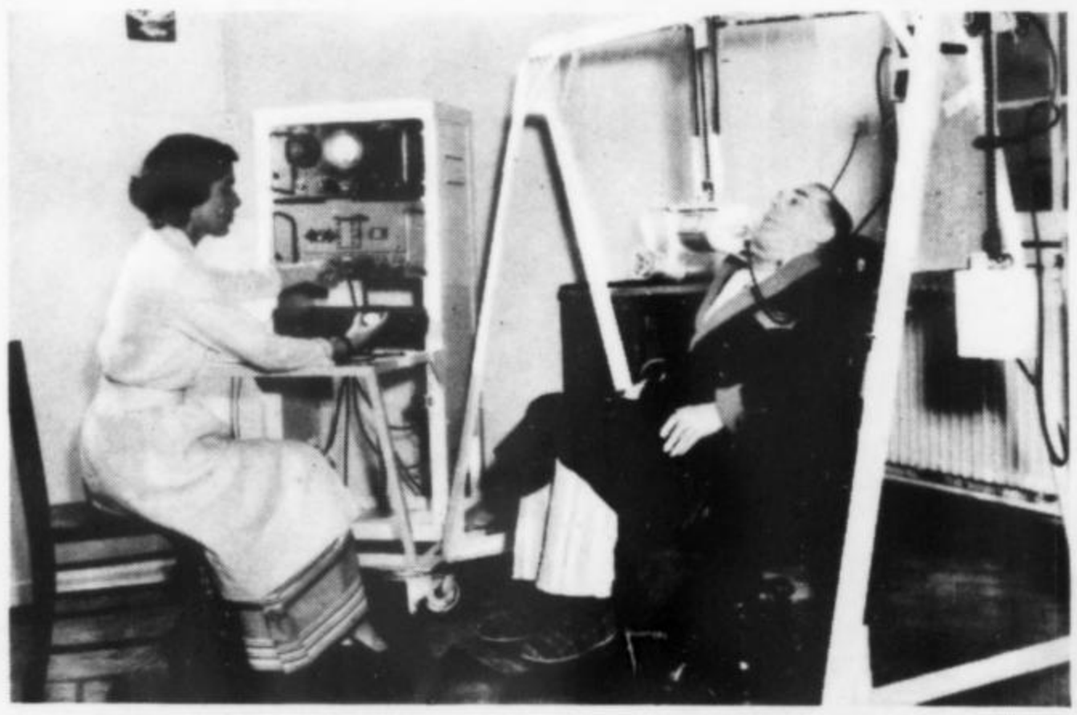
A NEW POWER TO SERVE HEALING AND RESEARCH

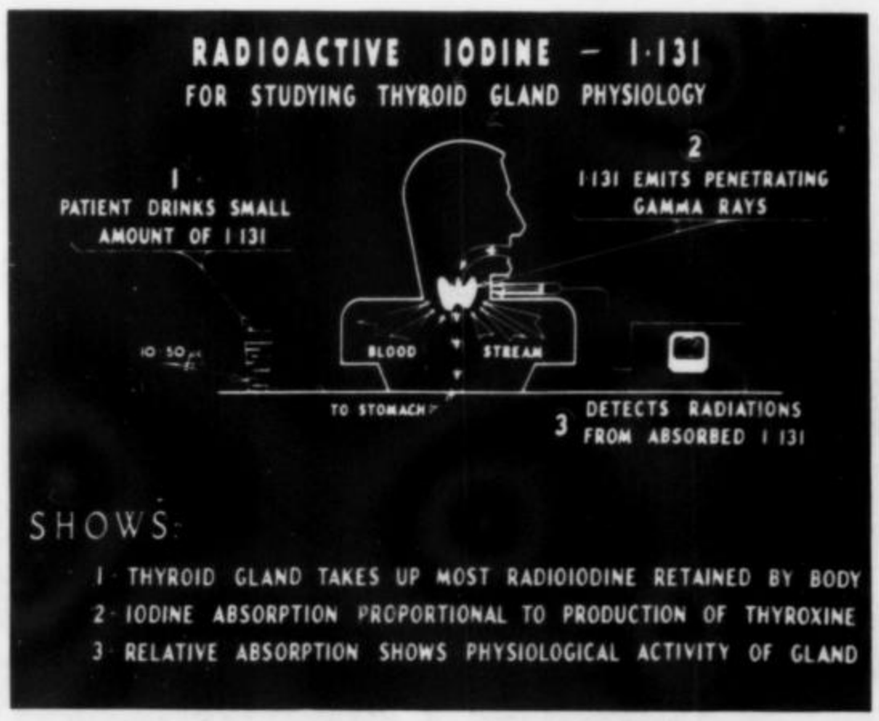
One of man's greatest hopes has been that he can eventually control disease, and today, greater opportunities exist than ever before for mastering it. Atomic energy is the amazing tool which now helps doctors to learn the processes of the human body and to fight illness. Radio-isotopes—substances containing the atoms which give off radiations and which are now being produced in ever-increasing quantities—have been described by doctors as the most important discovery since the invention of the microscope. In healing, isotopes with strong rays penetrate the affected area of the body and attack disease. In research, isotopes with weak, harmless rays are swallowed or injected and their rays trace hidden changes in the body. Photographs on this page and overleaf illustrate some of the ways in which the energy in the atom is being used to fight disease.





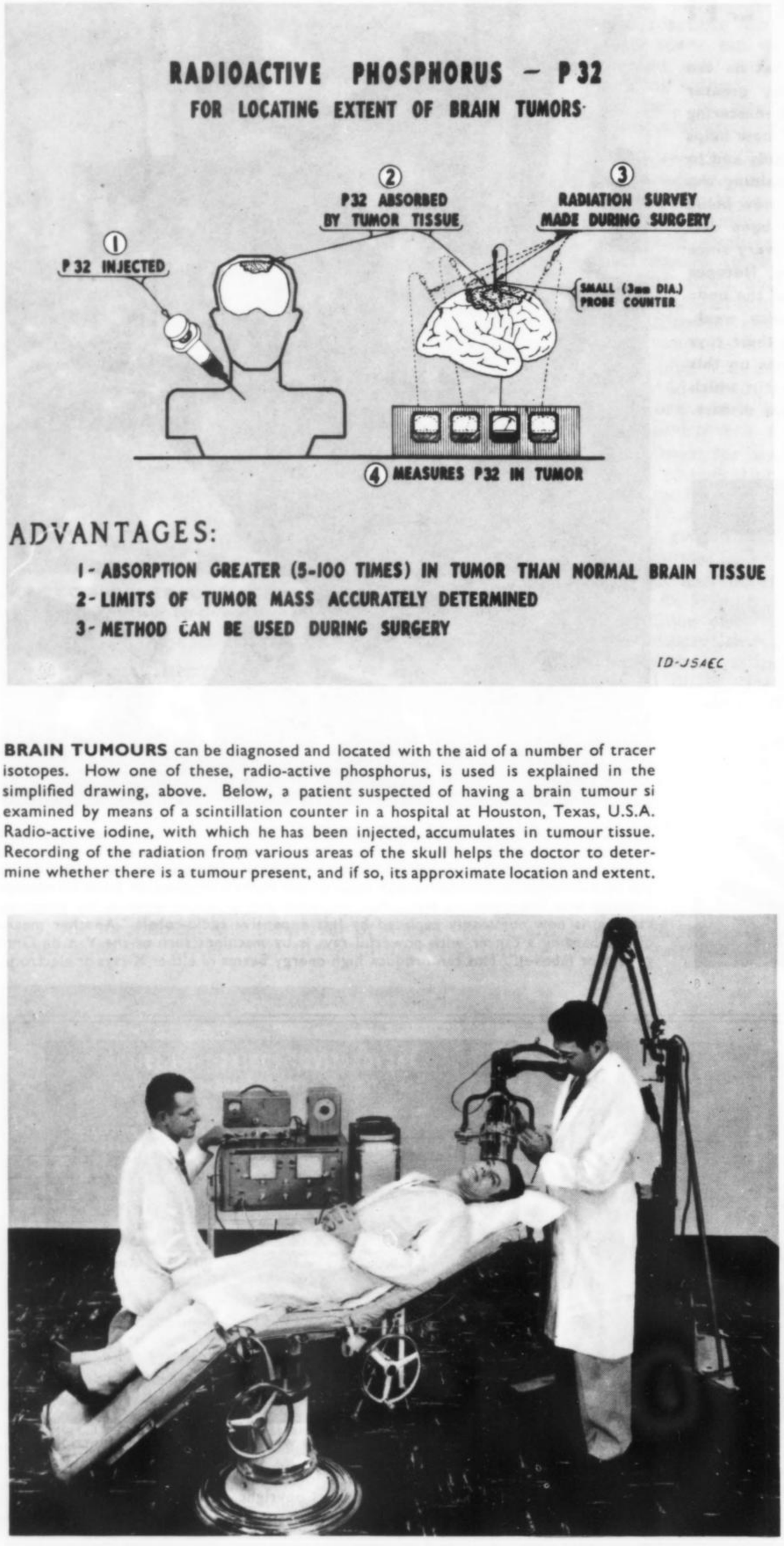
TRACKING DOWN AND ATTACKING CANCER. Radio-isotopes are used as "tracers" to locate cancers because these absorb some radio-active substances more than ordinary tissues. Photo, left, shows how a cancer has been charted by use of a scintillation counter which records the radiations given off from an isotope injected into the patient's arm. Radium, once the principal weapon for attacking cancers, is now commonly replaced by less expensive radio-cobalt. Another means of bombarding a cancer with powerful rays is by machines such as the Van de Graff generator (above). This can produce high energy beams of either X-rays or electrons.



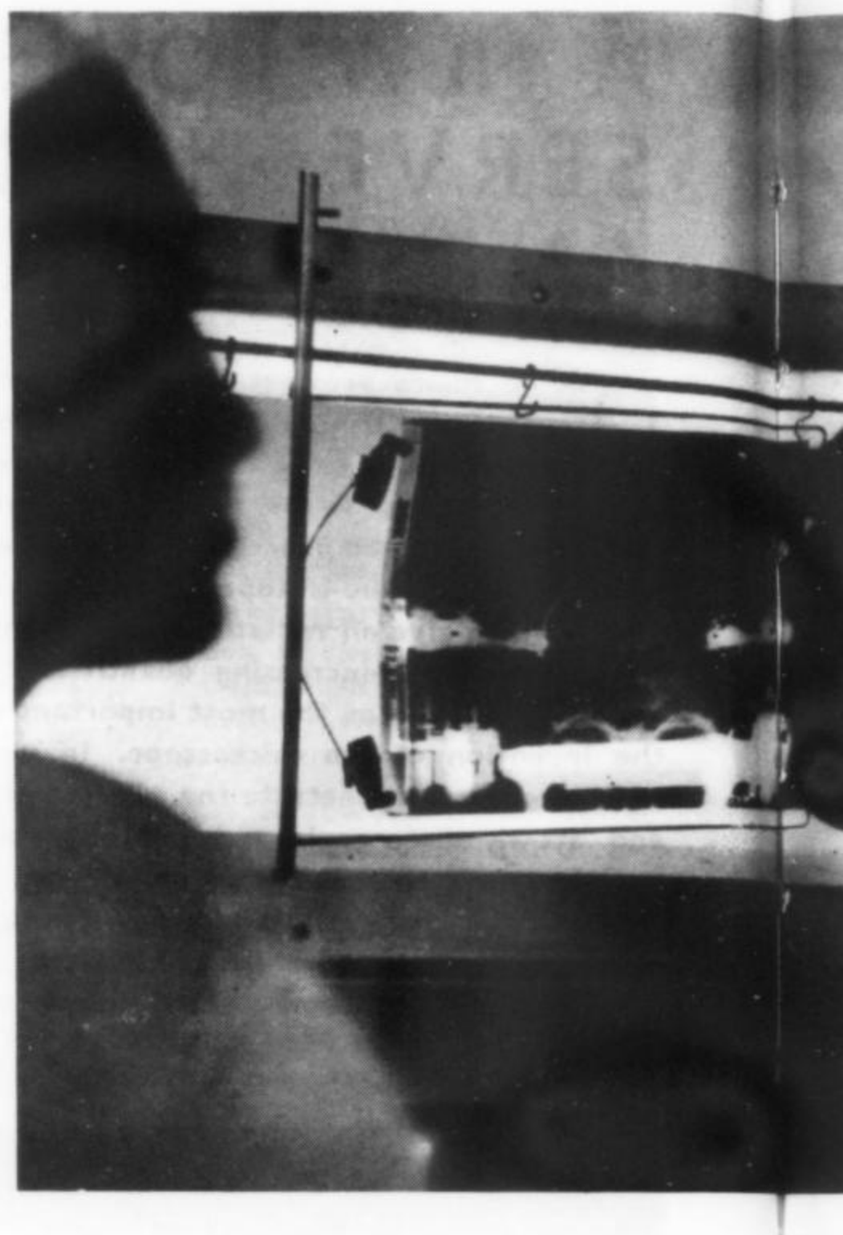


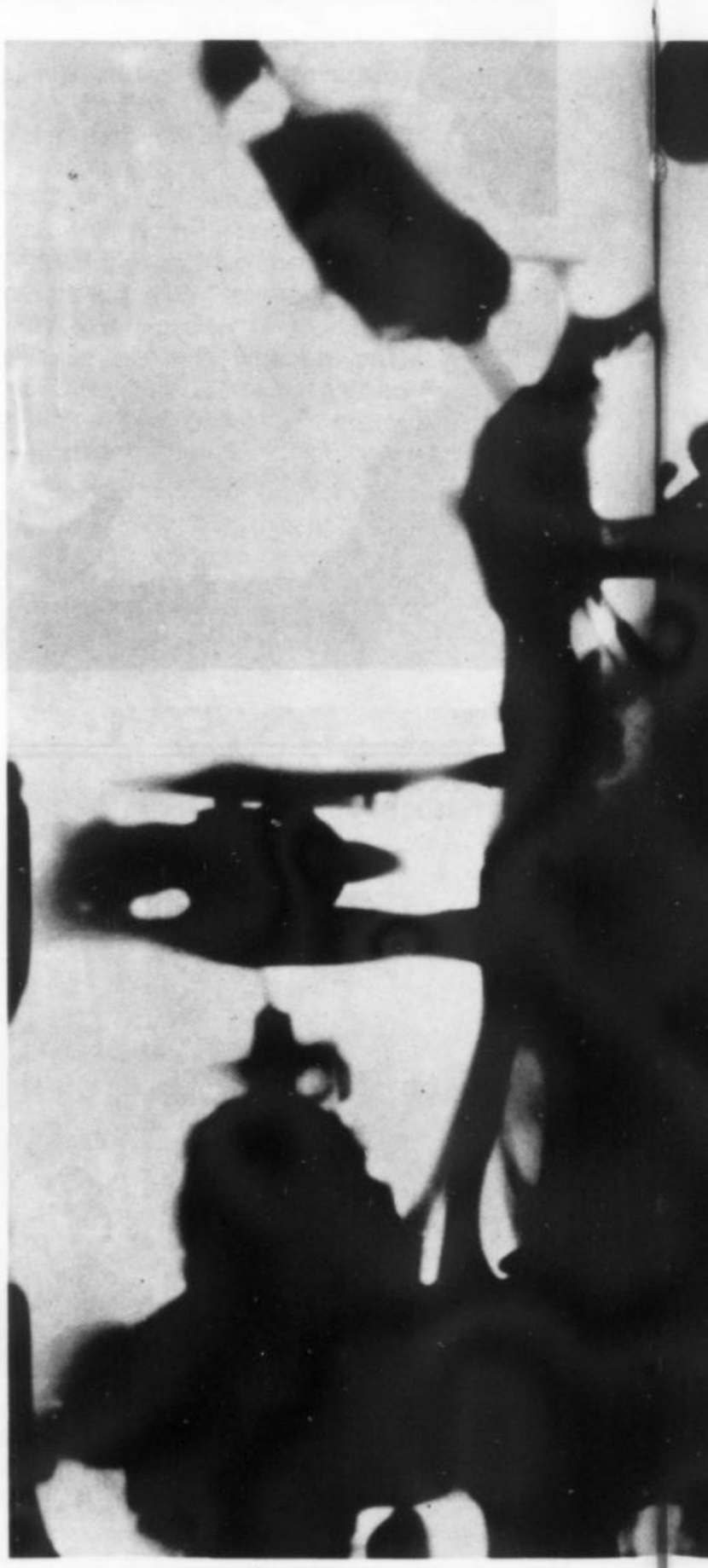
RADIO-ACTIVE IODINE is a tracer isotope which tells doctors how the thyroid gland is working. Patient drinks a small amount of radio-iodine which is largely taken up by the thyroid gland. This absorption is proportional to the gland's production of a hormone called Thyroxine. Measurement of the amount of radio-iodine absorbed thus shows whether the thyroid is functioning normally. Greatest use made of isotopes is for tracer techniques. (Photos COI Crown Copyright Reserved and USIS).

ATOMS IN THE SERVICE OF MEDICINE *(Continued)*



BRAIN TUMOURS can be diagnosed and located with the aid of a number of tracer isotopes. How one of these, radio-active phosphorus, is used is explained in the simplified drawing, above. Below, a patient suspected of having a brain tumour si examined by means of a scintillation counter in a hospital at Houston, Texas, U.S.A. Radio-active iodine, with which he has been injected, accumulates in tumour tissue. Recording of the radiation from various areas of the skull helps the doctor to determine whether there is a tumour present, and if so, its approximate location and extent.





PLANTING SEEDS OF RADIO-GOLD

The use of powerful tissue-destroying rays from radium is well established in the treatment of cancers. But radium has a long radio-active "life" and if implanted in cancer tissue must be removed after a time. Today several kinds of radio-isotopes are replacing radium for implantation. One of these is radio-gold, which has a half-life of three days. (The "half-life" is the time taken for the activity of a radio-active substance to decay to half its original value). As it is also inert in body tissues, it can be placed in them and forgotten. Photographs (top of page) show some phases in localization of a deep-seated brain tumour and its treatment with radio-gold grains at the Sainte-Anne Hospital in Paris. Use has been made of what is called the Stereotaxic method for locating an exact point (the site of the tumour, in this case) by taking measurements from three directions, with a specially developed apparatus. Above, doctors examine a radiograph of the patient's skull taken while the head was held in the frame of the Stereotaxic apparatus. Centre, the apparatus itself. Right, after injecting patient with a radio-isotope, surgeon obtains confirmation of the tumour site. Inserting a needle-like probe, combined with a Geiger counter, he is able to pin-point the exact depth (to within one millimetre) of the tumour because of the stronger radiations which come from the tumour tissues due to a greater concentration there of radio-active isotope, as compared with those from normal tissue. Afterwards, through the same tiny hole in the skull, he places grains of radio-active gold in the centre of the tumour with the aid of a special instrument. Photo, left, is a radiograph taken after two grains of radio-gold had been placed in a brain. Outlines of two needle-like instruments used to implant the gold are shown, and, slightly below their points, the two grains of radio-gold are seen as black specks. (Photos USIS by André Steiner.)

ISOTOPES

16.0000
14.008
12.01
32.06
35.457
39.944
55.85
54.93
79.916
83.7
97.8?
101.7
126.92
131.3
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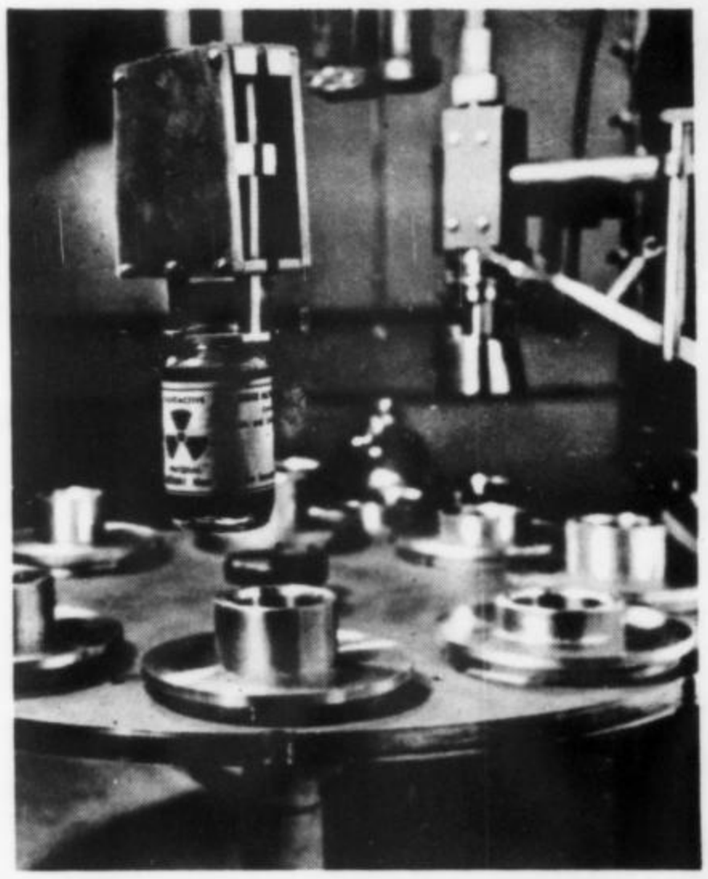
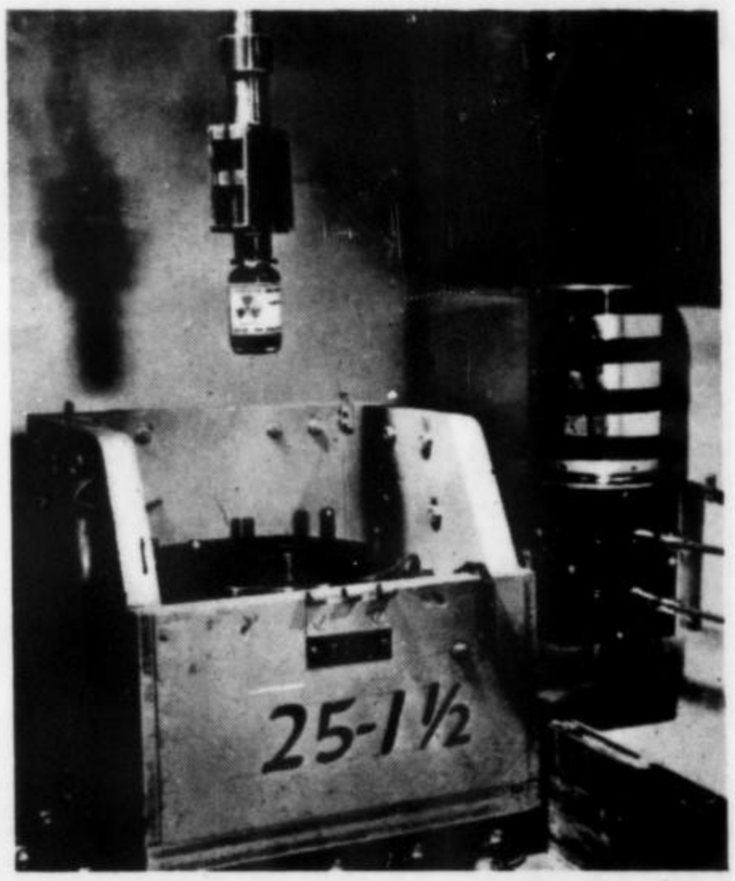
190.2
End of the 4-orbit series
End of the 5-orbit series
End of the 6-orbit series
DANGER
RADIOACTIVE
ISOTOPES





REMOTE CONTROL devices are used for handling those radio-active isotopes which emit dangerous radiation. Photos show how this is done at Oak Ridge National Laboratory, U.S.A. from where isotopes are sent to many parts of the world for use in industry, medicine and agriculture.

Devices for bottling and transferring radio-active solution shown here are operated by personnel who are protected by two feet of concrete shielding. Operation is observed by means of overhead mirrors and a periscopic device fitted on the handling tongs. (Photos USIS).

...and the hazards of radiation

As soon as atomic power begins to be widely used by industry throughout the world an important flow of by-products will come from the atomic furnaces that provide this power. And important and valuable as is the energy to be obtained from the atom, it is safe to say that these by-products of the atomic furnaces will be at least as valuable.

When an atom of uranium or thorium undergoes fission it splits into two or more smaller atoms. The velocity of these fragments becomes useful as heat but the new atoms remain buried in the reactor core. They are subjected there to a continuing intense bombardment by neutrons. This induces further nuclear changes and in their final form nearly all these atoms are so charged with energy that when they are later separated from the remaining uranium they are intensely radio-active.

Similarly, almost any other material inserted into the core of the reactor, by means of a special inlet tube, for instance, is also so bombarded that it emerges in a strongly radio-active form. As has been explained in an earlier article of this series, these new forms of otherwise stable atoms are known as isotopes and, when they are radio-active, as radio-isotopes. The core of a reactor is an immensely powerful device for manufacturing them.

The radio-activity consists of atomic disintegrations which are small continuing atom-by-atom explosions. The energy or tension in the atom of a radio-isotope is, in effect, relieved by the ejection of an electron, or an alpha particle and is accompanied by an intense emission of very short ether vibrations, called gamma rays, which resemble X-rays except that they are usually much more penetrating than any X-rays.

Isotopes of the various elements differ in the rate at which they decay and give off their energy. Some complete the process in a small fraction of a second, others in minutes, hours, days, years or even centuries. Obviously those in which the process is rapid give a very intense radiation while they last. Those that require years or centuries to decay give relatively only feeble radiations at any time.

There is thus an enormous variety of isotopes. The total number known at present is close to 1,300 of which about 800 are radioactive and more than 150 are useful and stable enough to be kept in stock on shelves for sale. Some are used for the intensity or penetration of their rays and others because their rays are feeble. The type of ray desired for specific practical effects also determines the choice of an isotope. Furthermore, the isotopes are chemical elements such as carbon, iron, phosphorous and gold, and they may be chosen for use because of their normal chemical reactions.

Before the days of the atomic reactor most radio-active materials were relatively weak. One of the strongest was radium, long used in the treatment of cancer. In those early days it was sold in milligrammes, thousandths of a gramme and cost approximately $100 per milligramme. When the women of America honoured Madame Curie toward the end of her life, they presented her with a whole gramme of radium at a cost of more than $100,000.

All the purified radium in the world amounts to less than 2,500 grammes — a little more than five pounds. Modern reactors however produce radio-active isotopes in quantities thousands of times as powerful as radium. A quantity of radio-active cobalt that is equivalent to 10 kilogrammes of radium — 10,000 grammes or 10 million milligrammes — can now be purchased at a reasonable price.

With such materials radiation effects can be obtained that were hardly conceivable ten years ago. For instance, the University of Michigan in the U.S.A. has recently announced that pork briefly exposed to the intense radiation from an isotope of cobalt can be freed of the trichina parasites. About 18 % of all pork is infected with these dangerous worms. The way trichinosis is avoided today is by cooking pork thoroughly.

For another example, research men at Oregon State College in the U.S. have reported that potatoes similarly exposed "are in perfect condition after almost two years in a bin under commercial storage conditions." The U.S. Army is now studying preservation of food by means of radiation from radio-isotopes without using refrigeration. It is possible completely to kill the bacteria, especially in meats, but perhaps also in fruits and vegetables, so that the food will not spoil and can be exposed on the shelf for many weeks without deterioration.

Such uses of intense rays are closely related to the radiation hazard in the vicinity of an atomic reactor. These are always enclosed within heavy walls of lead and concrete to prevent exposure of the operators to the rays. It must be said that the reactor also emits high-speed, very penetrating neutrons but the radio-isotopes do not.

One of the most hazardous operations in the world is the removal of the core of an exhausted reactor and the disposal of the enormously radio-active waste products that have accumulated in it. Special devices are used, such as allowing the spent uranium rods to fall directly from the reactor into a large pool of water and into an underwater cart by which they are removed for safe disposal. But that disposal is

A DRY BOX is used where the handling of substances involves risk of poisoning. The research worker here is handling a radio-isotope with rubber gloves let into the walls of the box. Substances with toxic properties are placed inside the dry box through the doors of small chamber at right. (Photo C.O.I. Crown Copyright Reserved).

itself one of the major problems of the atomic industry, for the intense radio-activity may in this case last for decades and part for centuries.

The reactor wastes have been buried in deep pits and they have been hauled far out to sea sealed in great blocks of concrete. Neither of these is satisfactory in the long run so that Dr. Ira M. Freeman, of Rutgers University in the United States, has suggested that one of the best uses to which a future space-rocket can be put is to send a container of radio-active waste far out into space where it would continue in an orbit around the earth or perhaps around the sun for ever, gradually exhausting its radio-activity. On the other hand, if the demand for radio-isotopes in industry, agriculture and medicine continues to grow the wastes of the reactor would provide an ample supply.

In spite of the radiation hazards, men working with the atomic reactors are very seldom harmed. In fact, the published figures show that accidents and injuries in the many large atomic plants in America are decidedly less in relation to the number of men employed than in ordinary industry. This is because the danger is understood and is guarded against. Not only are all dangerous operations conducted behind thick walls by remote control, but employees who may be exposed to radiation wear special clothing and all of them are constantly inspected by photographic and electronic instruments for any traces of radio-active contamination.

Precisely the same source of danger arises when the atomic bomb is exploded, except that in that case the radio-active atoms are very finely blown throughout many cubic miles of the thin stratosphere. There are many millions of cubic miles of air above the earth and the dispersion by the bomb itself, by heat and by winds is so great that the concentration of radio-active material in the air is almost vanishingly small. But it can be detected by sensitive instruments. It is thus that the explosion of an atomic bomb can be detected on the other side of the earth.

There is no doubt, however, that the slow accumulation of radio-active material from successive bombs and especially from hydrogen bombs, which are thousands of times as powerful as uranium bombs, would eventually produce concentrations of radio-active materials in the air that would harmfully affect all living things. In September 1954, Dr. E. D. Adrian, President of the British Association for the Advancement of Science warned that "we must face the possibility that repeated atomic explosions will lead to a degree of general radio-activity which no one can tolerate or escape."

It is not now possible to estimate whether this point will be reached after the explosion of a hundred atomic bombs or after a few thousand. Experts agree that the two score of bombs that have been exploded up to now have done no harm. The one exception was one hydrogen bomb ex-

Lasting fire from the atomic furnace

ploded over the Pacific which did shower radio-active dust over a much larger area than had been expected and caused burns on 23 unfortunate Japanese fishermen of whom one has since died. Their boat, the "Fukuryu Maru", was between 70 and 90 miles from the centre of the explosion. Such danger from the explosion itself, is, however, enormously greater than from the isotopes dispersed at great heights and over a wide area.

Nevertheless the radiation hazard needs more careful study and on a motion of the Japanese delegation at the Montevideo General Conference in December, Unesco was authorized to co-operate with the World Health Organization (WHO) in studying protection against the effects of radio-activity on life in general.

The sterilization of meat and vegetables by intense rays from powerful isotopes, though technically possible, is still too expensive. The use of isotopes for sterilization will come first in the case of more valuable materials such as penicillin and other antibiotics. These drugs are injected or used internally and so must be completely free of all bacteria or other infections, yet they cannot usually be heated or boiled to sterilize them. The vials containing the drug can be briefly exposed to an intense radiation equal to many kilogrammes of radium and can thus be safely and completely sterilized in the cold.

Another use was recently demonstrated by Admiral Lewis Strauss, Chairman of the U. S. Atomic Energy Commission, who carried with him a small box weighing about 20 pounds, light enough to be carried on a battlefield, but which gives sufficiently intense gamma radiation to equal that of a powerful X-ray machine without using any machinery or power supply. The isotopic rays from the portable container can be used as X-rays are to detect flaws in metal and in machinery or to make examinations of persons injured in accidents, for instance.

Where no intense radiation is demanded the isotopes are already cheap enough to be in industrial use. Large quantities are available, for instance, to stimulate the luminosity of fluorescent materials, hence to replace expensive radium in luminous watch and clock dials and on advertising signs.

An isotope of strontium is being used by the U. S. Navy on many thousands of self-luminous markers which are twice as bright at night as a sheet of white paper in full moonlight and may be had in almost any colour except deep red. Here the cristalline material is stimulated to luminosity by the rays given off by the strontium which decreases in strength at so slow a rate that the markers remain luminous for a score of years or more.

SHORT-LIFE ISOTOPES which must be employed within a few days following their activation in an atomic pile are despatched by air. Here a canister is being placed in the wing-tip of a South Africa bound aircraft at London Airport. (Photo C.O.I. Crown Copyright Reserved).

Another application is in the ordinary fluorescent tube. When isotopes are mixed with the luminous material they increase the conductivity of the air in the tube so that it requires less voltage to start the lamp and it starts much more quickly. A similar use is made of a tube of such materials weakly radio-active, where there is danger of sparks from static electricity. The faint rays make the air a sufficient conductor of electricity so that static does not accumulate.

A typical industrial use of the rays from these radio-active materials is in the automatic control of the production of thin sheets of paper or plastic, or the metal for making tin cans. As the sheet leaves the rollers which squeeze it to the desired thickness, it passes through an instrument that holds a small amount of radio-active material under the sheet and holds a detecting instrument such as a Geiger counter, over the sheet. The rays penetrate the sheet and are received and detected on the other side.

But if the sheet for some reason becomes either thinner or thicker than is desired, the amount of radiation received by the detecting instrument instantly increases or decreases as a result, because it is partly absorbed in the sheet. Thus the instrument is a constant and automatic inspector of the thickness and it can easily be adjusted to regulate the rollers and correct the error so as to produce a sheet of uniform thickness.

A suggestion of things to come was given by the Radio Corporation of America in a recent demonstration of a small electric battery which uses the actual power of the electrons that are continuously emitted from about half a milligramme of radio-active strontium, amplifies them in a modern "transistor", and thus achieves enough power to work a telegraph relay or work a telephone transmitter. Thus the tiny battery gives a current of 5 micro-amperes and one fifth of a volt. Small as it is, it is the first practicable conversion of atomic energy directly into electricity without the use of heat.

A well-known use of the direct rays from radio-isotopes is in medicine.

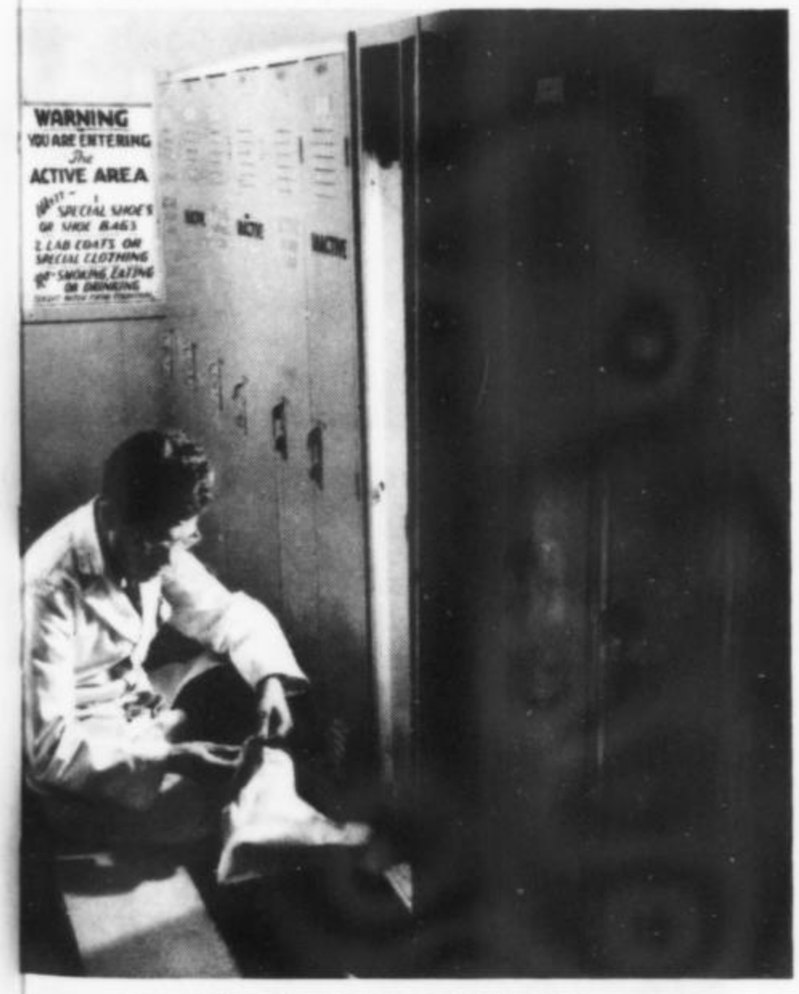
The use of the powerful tissue-destroying rays from radium is established in the treatment of cancers. They have the same effect as equally powerful X-rays but a cancer can often be reached with a small pellet or tube of radium that cannot well be reached by X-ray tube. The new radio-isotopes can be used in exactly the same way, but with the advantage that the amounts of radiation that can be obtained from them are far larger than in the case of radium and cost less.

The commonest substitute for radium is radio-cobalt. A small cylinder of metallic cobalt gives gamma rays equal to that of radium costing several hundred thousand pounds sterling. Such a piece of cobalt, weighing little more than an ounce is enclosed in heavy metal but an intense beam of radiation is directed through a small window at the cancerous growth.

In other forms, both radio-phosphorus and radio-gold are very conveniently used for this type of treatment. For skin cancers, an ordinary blotting paper is soaked with radio-active phosphate solution and when dry it is cut to the size and shape of the tumour, then is strapped to the tumour with adhesive. Radio-cobalt can be drawn out into a fine wire or cut into tiny beads which can be placed within the cancerous growth. And radio-gold can be formed into tiny grains which are fired directly into the cancer from a small "gun". In both cases they remain in the cancer until it is destroyed.

In another method of treatment, the

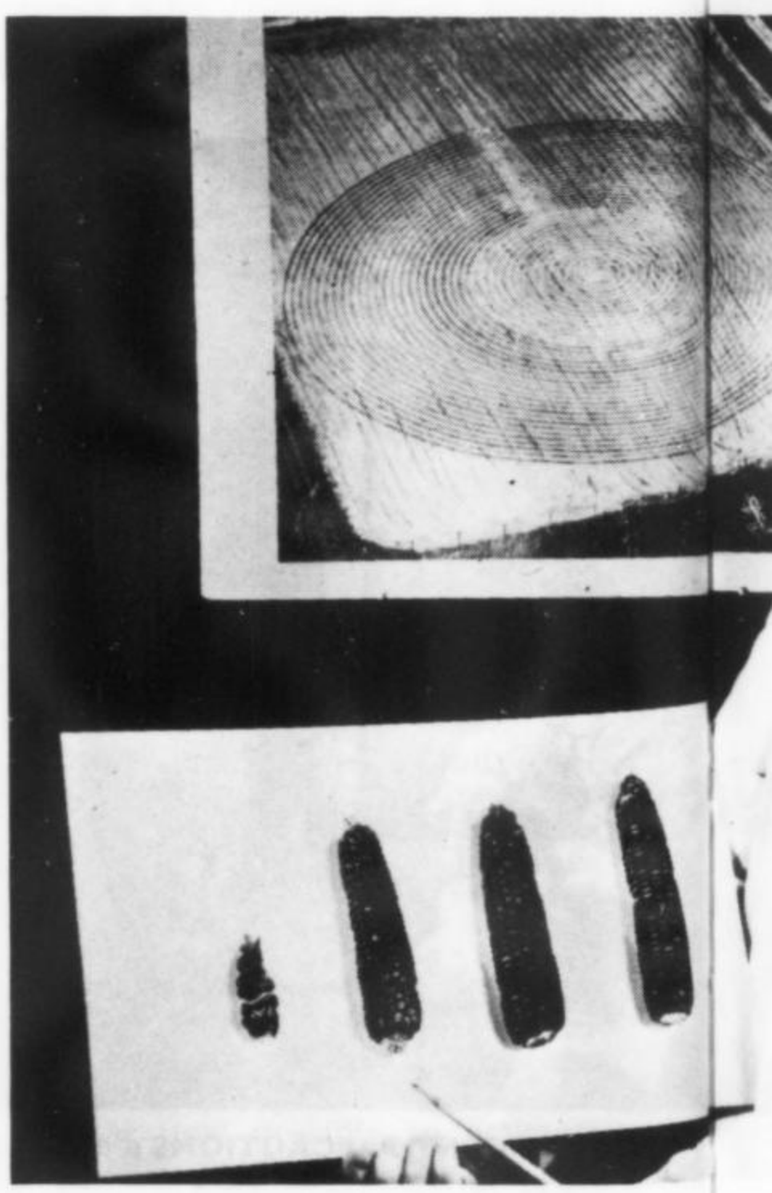
(Continued on page 35).



STRINGENT PRECAUTIONS protect atomic energy laboratory and plant workers against ingestion of radio-active gas or dust. Eating and smoking are forbidden in "active" areas. Outdoor clothes are left in one locker and work clothes in another. Here, a research worker puts on overshoes before entering a laboratory. (Photo N.F.B.).

TRACKING INSECT PESTS with radio-isotopes. Scientists at the Rothamstead Experimental Station, Harpenden, England, carrying out a series of experiments on aphids, a family in insect pests which include the greenfly and blackfly. Here, an aphid is being marked with radio-active paint before being put to feed on young turnip plants. These tracers reveal insect's migration from plant to plant. (Photo COI Crown Copyright Reserved).

PRESERVING POTATOES by exposing them to gamma rays was part of a study of radiation effects on plants made by agricultural scientists at Brookhaven National Laboratory. Irradiation of unsprouted tubers kept them firm after months underground, where they would normally have rotted. Another experiment showed that when radiation is spread over a protracted period, living organisms can tolerate a total exposure which would cause serious injury if concentrated into a short time. (Photo USIS).



GAMMA FIELD with radio-active cobalt at its centre at Brookhaven National Laboratory, as seen from the air, is shown in background of this photo. Scientists study hereditary changes due to gamma rays. Four ears of corn shown here were grown at different distances (seen

THE WAY TO BIGGER HARVESTS

NEW PLANT STRAINS, capable of yielding more food per plant are being developed by scientists at Brookhaven National Laboratory, New York. Vegetable crops have been exposed to radio-activity, and since radiation accelerates variations of strains, years of time may be saved. As changes occur the plants are selected and crossbred. Corn variations include changes in colour, sweetness and other characteristics. Photo shows a new hybrid, about as tall as a man, which has been developed. Photo USIS).

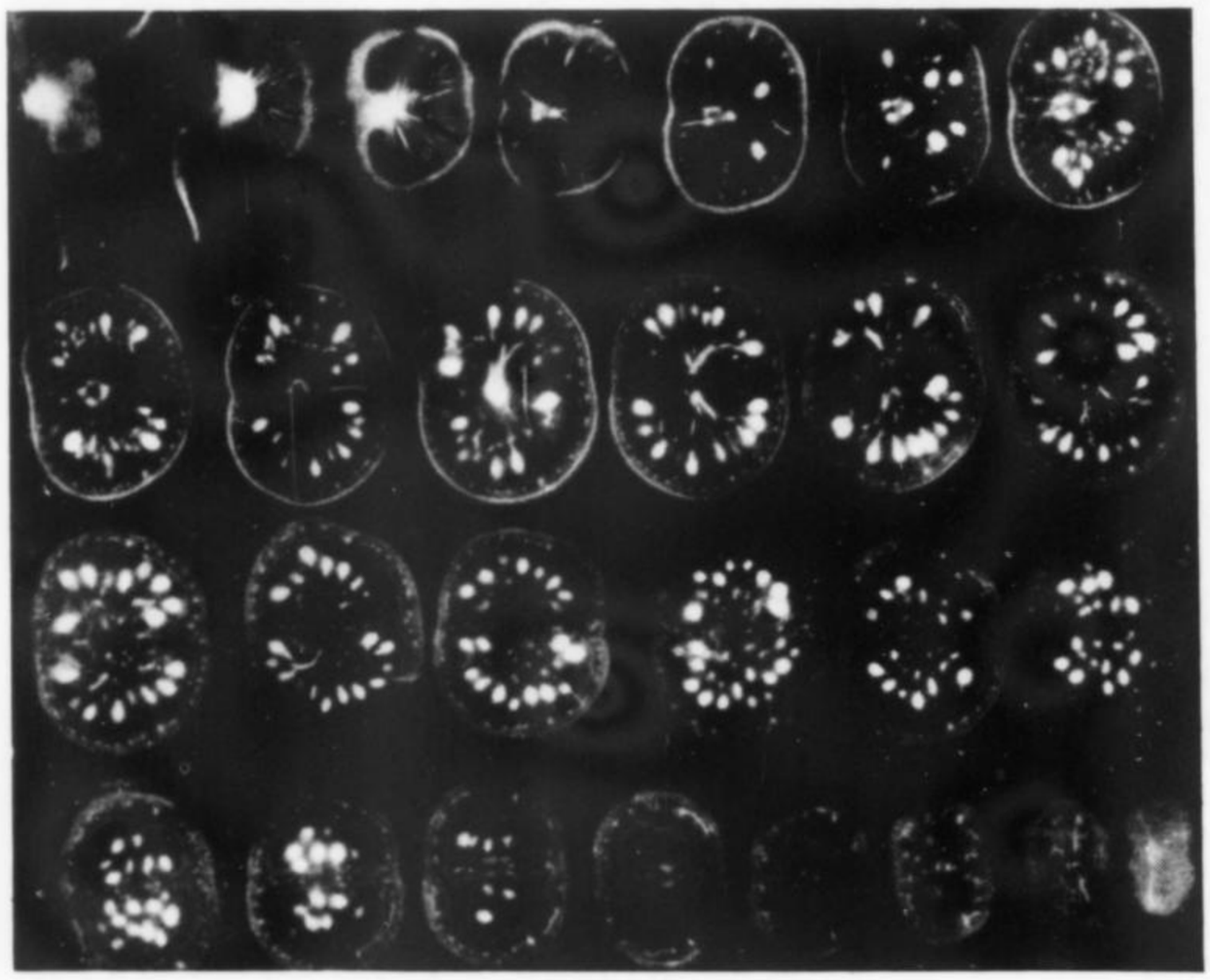
The world's poorly fed people number hundreds of millions. In some countries famine hovers at innumerable doorsteps every year. Yet more and better food for hungry peoples could be produced if better types of crops could be developed, and if agriculturists could learn more of the secrets of plant life and growth. In time, atomic energy may help to dispel the spectre of hunger from homes all over the world. It can guide plant scientists to improved ways of raising crops, teach them how to combat insects and plant diseases more effectively, and even create new types of plants which yield a larger harvest or better-quality produce. Using radio-isotopes as "tracers" scientists have been able to learn much about plant growth and how to make the best use of fertilizers. One authority has said: "The advances made with isotopes in the knowledge of phosphate fertilizers during the past four years is equal to and may exceed the progress in this field during the preceeding 50 years." Some day, scientists may be able to create food in laboratories. The day when hungry peoples will be fed will come more quickly if atomic knowledge is shared by all.

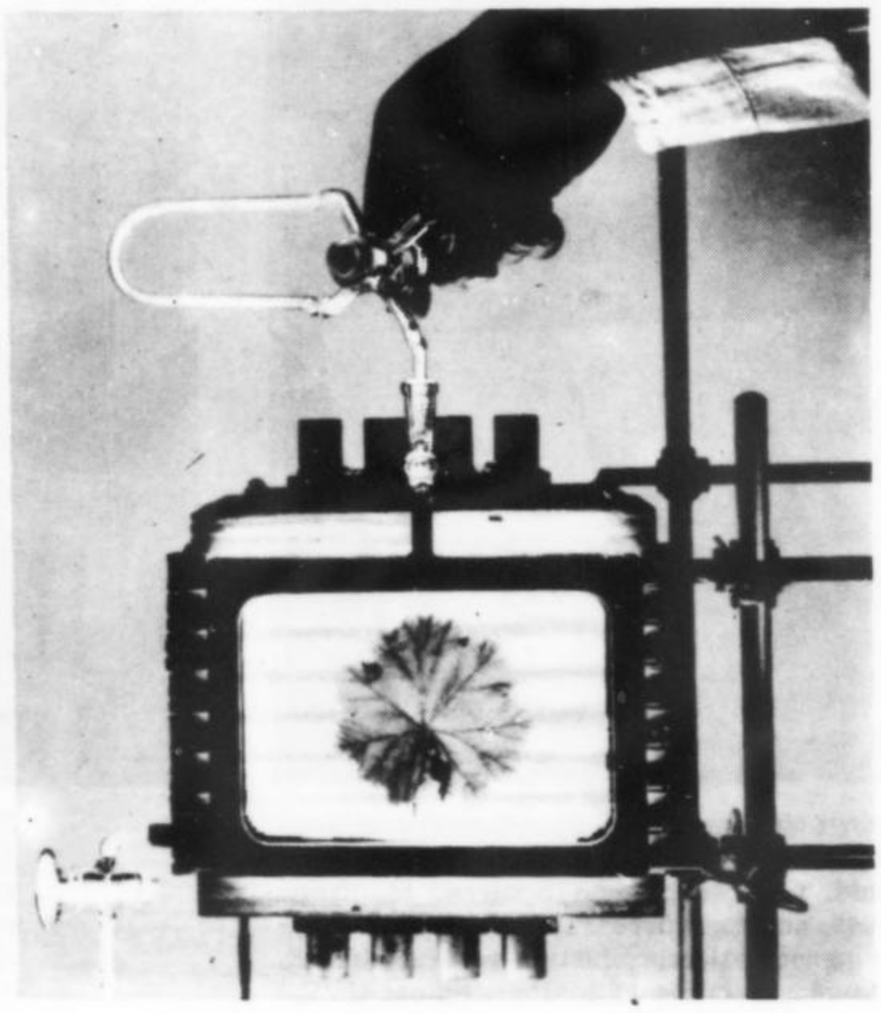
as rings in aerial photo) from the cobalt, which is lowered into ground while men work in field. Greatest changes occurred in plants nearest centre where rays were strongest, showing normal reproduction can be altered from one generation to another. (Photo USIS).

DESTROYING BACTERIA that cause food to deteriorate. At the Massachusetts Institute of Technology, filets of codfish are placed on a moving belt for exposure to high intensity rays which kill the food-spoiling bacteria in one second. Tomatoes, fish and raw meat have been sterilized in this way and kept in storage without deterioration for ninety days. This method of food preservation is still in experimental stage, but may eventually play an important part in cutting down world food spoilage. (Photo USIS).

PLANTS TAKE OWN PHOTOS

Using radio-isotopes, scientists are today probing deeply into the greatest secret of nature — how green plants use the sun's energy to build their substance from the water and carbon-dioxide of the air, releasing oxygen in the process. Photosynthesis, as it is known, is the basic biochemical process underlying all life, since it provides the ultimate source of food for all living things and replenishes the oxygen in the atmosphere. It is an apparently simple reaction in which the molecule of water and that of carbon dioxide are combined, lose some oxygen and form starches, sugar, cellulose and more involved chemical materials. So far man has been unable to duplicate the process, but the availability of a faintly radio-active isotope of carbon has given much information to scientists and may eventually explain the reaction completely. Exposed to radio-active carbon dioxide for only one minute, green leaves of certain plants were found to have already manufactured over fifty separate compounds. Photo, below right, shows one of the detailed studies of the mechanism of this basic plant reaction. Isotopes are now widely used in tracing other complicated plant processes of growth and food production. Photo, right, shows an image made by a bean plant containing radio-active materials. Twenty-five millionths of a gramme was applied to one leaf. During the next three days the material was absorbed into other parts of the plant. In photo below, tomatoes have "taken their own photographs" after being tagged with radio-active isotope and placed on photographic plates. Radio-active zinc has concentrated in the seeds. Experiments like these will not enable man to dispense with plants for food production, but may well mean that food production by plants can be greatly improved. (Photos USIS).





Geiger counters on the mosquito's trail

(Continued from page 31)

radio-isotope can be given internally or can even be swallowed to find its way into the blood stream. It is absorbed from the blood by cancerous tissue. This is one of the respects in which cancer differs from ordinary tissue: it does absorb the radio-isotope. Consequently, one disease, in which the red blood cells are formed in such profusion as to clog the blood vessels, can be treated by radio-phosphorus which sharply reduces the production of red blood cells in the body for a period of about a year.

Isotope's travels

In these cases, the powerful rays are used directly. But there is an entirely different use of radio-isotopes involving small quantities of isotopes with very faint radiation, far too weak to do any harm, indeed too weak to be detected by anything but sensitive specialized instruments. These are known as tracer isotopes because they reveal their presence by their faint radiation, wherever they go, no matter through what chemical reactions they are put, and thus permit their detection at any point of their travel or adventures.

By such means it is possible to follow the course of chemical atoms through the human body, for instance, and not only to locate them physically but to detect the chemical changes through which they have gone. By far the greatest use of radio-isotopes is in this new technique of tracing the course of mechanical action, of chemical reactions or biological processes.

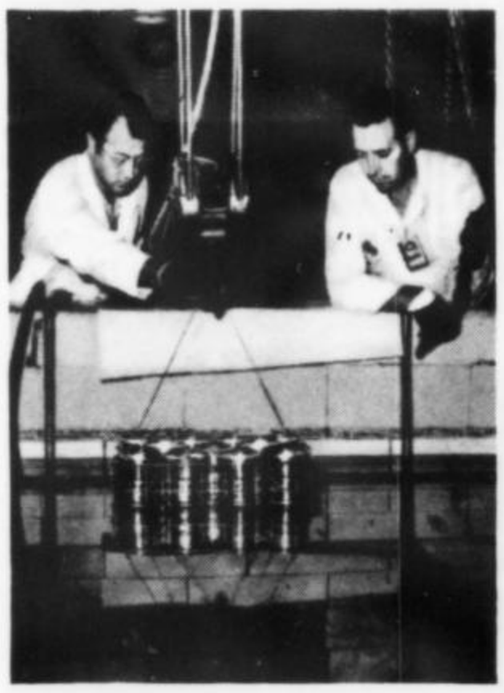
Another example of the direct industrial use of the radiations from isotopes is the control of the flow of oil through long pipe-lines. Such a line can seldom be used for long periods to deliver one single grade or variety of oil. Instead, different oils are pumped through, one after another. It is important for the operators at the receiving end to know when one grade or one shipment is at an end and another is to begin in the continuous flow of oil from the pipe.

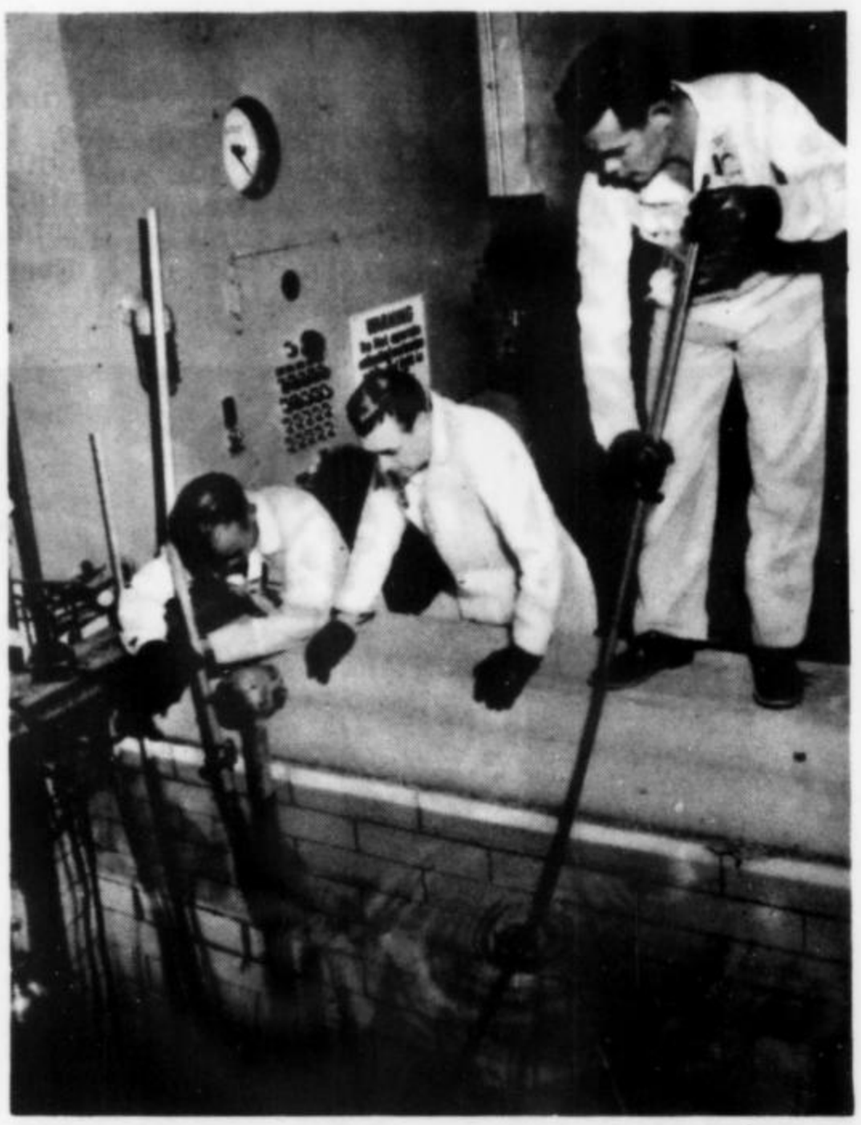
Radio-active piston ring

This is now done by mixing in a at the boundary between one small quantity of radio-active oil batch and another as they are pumped into the pipe. When that radio-active oil reaches the receiving station, perhaps hundreds of miles away, the radiation counters immediately detect its arrival so that valves can be adjusted to shift the flow from one tank into another.

Another example from the oil industry illustrates the use of isotopes in research. The Shell Petroleum Company in England now measures friction and engine wear by exposing a piston ring to bombardment by neutrons until a small part of the iron is converted to a radio-active isotope. The ring is then fitted in an operating engine. As it wears by friction the debris goes into the crank case oil and that oil is then pumped through a sensitive detector of radiation. The very small quantity of weakly radio-active iron is sufficient to be measured and therefore to give an immediate indication of the amount of wear on the engine. This method of testing avoids the long operation of the engine and the troublesome analysis of the oil for iron, and can show the effect of different lubricants within minutes.

The California Research Corporation reports that in similar researches a programme of friction studies that would have taken 60 years and cost a million dollars was completed in this way in four years at a cost of thirty-five thousand dollars. Others have employed this method to show that high speed driving on the open road causes only about one-third of the engine wear that is involved in city driving. The end result of these researches, however, is the reduction of friction and the improvement of lubrication.





TESTING MATERIAL in a special reactor at an atomic research centre in the U.S.A. On left, cans of meat are inserted through the water canal leading to the reactor. Tests will show how the meat and containers have been affected by radiation. On the right, technicians are using long-handled tongs to remove an aluminium tube filled with radio-cobalt. This will be shipped away for use in cancer therapy.

Even mosquitoes can be traced by radio-isotopes. Mosquito larvae that swim in a very weak solution of radio-phosphorus remain radio-active all through their lives and their presence can be detected with Geiger counters. The habits of mosquitoes are now being studied by this method to learn how long they live, how far they fly, and what they feed on. It is expected that similar treatment of birds may give reliable information on bird habits and especially on their migrations.

Another very practical application of the tracer technique which has saved a large amount of money for the farmers is in the study of the action of fertilizers.

For example, phosphate is a necessary plant food and is a component of nearly all fertilizers. It is an easy matter to produce the isotope of phosphorus that is weakly radio-active and to mix it with the normal phosphate in the fertilizer. Since it constantly gives off a weak and harmless radiation that can be detected by proper instruments, it is a very simple matter to follow or trace what happens to the phosphorus in the soil and the plant.

Important agricultural information has thus been obtained. For instance, Swedish investigators have found that phosphate in a fertilizer is taken up by the plant roots almost immediately when it is spread on the soil; there is no delay. American investigators have discovered that pasture grasses can take up phosphate that is spread over their leaves and roots, so that old pastures can be rejuvenated by phosphate without the need for ploughing.

Even more interesting is the fact that maize, sugar beets, tobacco and cotton take up phosphate from the fertilizer only during the early stage of growth. Fertilizer spread on the soil late in the season is of no value to these crops. On the other hand, potatoes take up phosphate from the fertilizer in large quantities throughout their entire growing season.

Finally, it has been found that phosphoric acid added to irrigation water is just as effective as fertilizer spread dry on the soil. All of these results were obtained by measuring the amount of radio-active phosphorus detected in the growing plant. While its quantity is small, like the black sheep in a flock, it can reliably be used for measuring the fate of all the phosphorus.

Many other tracer elements utilized in this manner have given information of value to the farmer. Radio-active potassium, painted on a branch of a dormant plum tree, in weather below freezing point was found to enter the sap and move several feet both up and down the branch in spite of the fact

Body rebuilt every year

that the sap is supposed to be motionless in winter. On the other hand, in summer the phosphorus moves all the way to the roots within twenty-four hours.

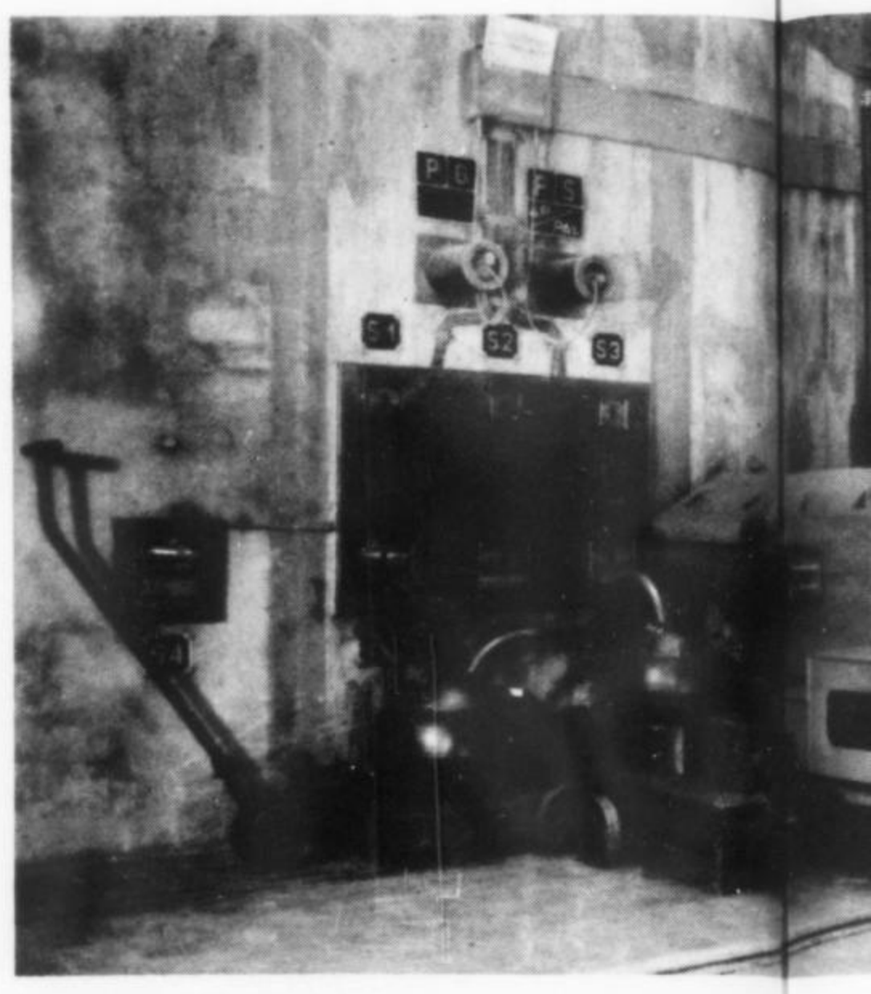
Another agricultural application of this tracer technique with radio-isotopes is in the study of insects and fungi. Radio-iodine has been used to study the spread of the oak wilt fungus, through the roots and from the roots of one oak to another. Insecticides also can be tagged with radio-isotopes. Thus it has been shown that plant leaves absorb insecticides principally on their under surface and do so only during the day.

Such work has also emphasized the difference between broad-leafed plants and narrow-leafed grain and grasses in their response to weed-killers. A broad-leafed plant was found to absorb a weed-killer sprayed upon it and within two hours the entire plant is permeated with it. On the other hand, the grasses absorb very little weed-killer and what is absorbed stays on the spot without affecting the plant as a whole.

One of the first results of the use of "tracer" isotopes was the discovery that all the tissues in the body are in a constant process of replacement. It is natural to think of the body as a stable structure which uses food only to maintain its heat and for replacement of worn parts. This is not so. When fats, in which some of the hydrogen atoms have been replaced chemically by "heavy hydrogen" are eaten, the new fat is deposited in the fatty layers of the body while the older fats, already in the body, are burned for heat.

So, too, eating proteins which contain "heavy nitrogen" results in the use of the fresh protein for building body tissues, muscles and blood cells, while the proteins already present are oxidized and excreted. Every part of the body is thus constantly being rebuilt by a steady exchange of new materials from food to replace the established materials.

Every twelve months every human or animal body is completely rebuilt. Even the bones are thus rebuilt and the only exception is the iron, chiefly in the red blood cells, which is not rapidly replaced by new iron atoms in the food. This process is a fundamental to life, but would probably never have been discovered without the use of tracer isotopes.



PROTECTIVE TROLLEY is a device used at the Saclay Atomic Energy Research Centre, near Paris, to remove "hot" (highly radio-active) materials from the Centre's Atomic Pile. Running on rails alongside the

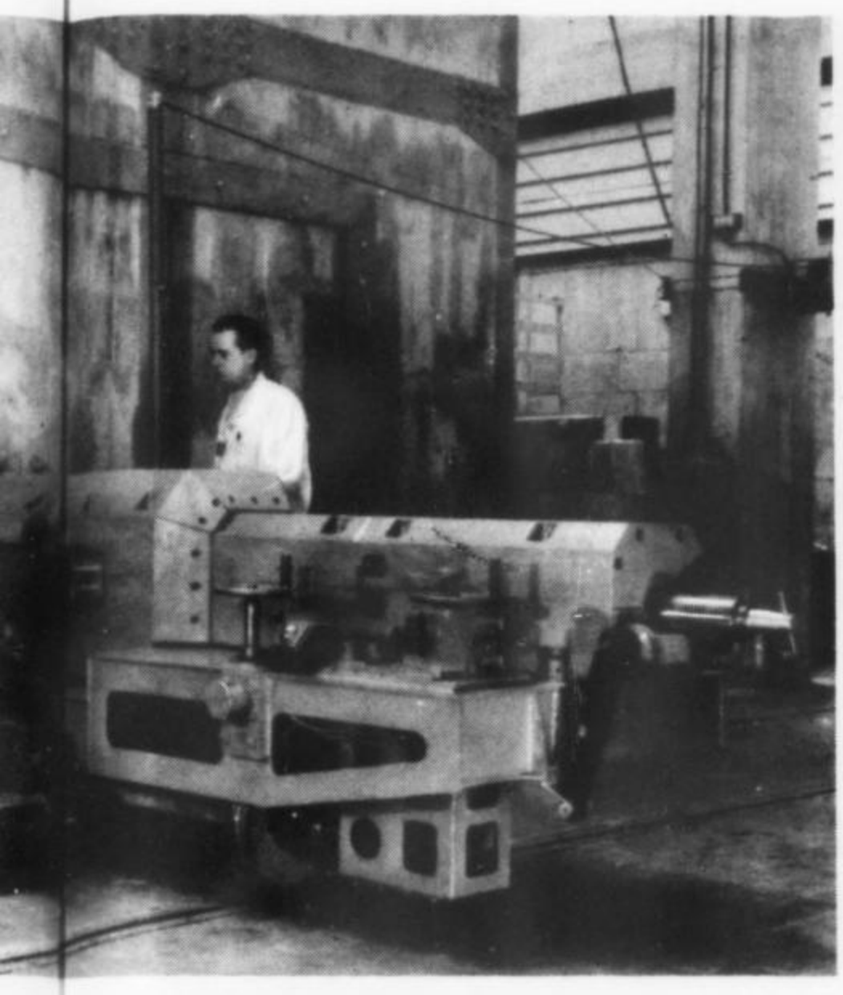
GIANT HAND has been built in the United States to enable atomic engineers to carry out operations in dangerously radiated chambers without exposing themselves to rays. The "O-Man" (contraction of "overhead manipulator") weighs 15 tons and can lift 7,000 lb loads. It combines enormous strength and gentle dexterity, for, among other feats, it can rivet, weld, solder, hammer and use a knife. Co-ordinated by remote control levers, its movement is controlled by an operator in a shielded adjoining room. (Life Photo).

Nature's secret process

THE most promising investigation of this sort is the study of the process by which green plants build their substance from the water and carbon-dioxide of the air. This reaction is the fundamental one for all life since all the green plants depend upon it and all other plants and all animals depend on the green plants. It is apparently a simple reaction in which the molecule of water and that of carbon-dioxide are combined, lose some oxygen, and form sugars, starches, cellulose, and more involved chemical materials.

Nevertheless, no one knows how the plant does it and man is unable to duplicate the reaction. But the availability of a faintly radio-active isotope of carbon has already given much information and may within the next year or two explain the reaction completely. This will not mean that man can dispense with plants for food production, but it may well mean that the food production by plants can be greatly improved once this reaction is understood.

The process involves the formation of carbon-dioxide gas from carbon which contains a small proportion of the radio-active isotope of carbon. The product is "heavy carbon-dioxide" but is used by plants in the presence of sunlight exactly as they use ordinary carbon. The result is that the radio-active carbon is built into the materials of the plant and its presence and location in the plant can be detected immediately.



the reactor it can withdraw isotopes and other materials which have been activated inside, through the small square doors seen on left. Its heavy covering protects operator from rays. (Photo C.E.A.).

LEAD BRICKS are sufficient protection for minor laboratory operations where only low radiation strengths are involved. Research worker here is guided by reflection in the mirror. Safety precautions in atomic laboratories are not intended to give 100% protection against radio-active radiations, but rather to ensure that any dose received does not exceed a safe level. (Photo USIS).

When the green leaves of certain plants were thus exposed to radio-active carbon-dioxide for only one minute, at least fifty separate compounds were found in the leaf, tagged with radio-carbon. When the time of exposure to sunlight was reduced to two seconds, the leaf had already manufactured two or three compounds from the carbon-dioxide of the air.

It turns out that the first products made by the plant are compounds of phosphoglyceric acid which thus are shown to be steps in the manufacture of fruit, or grain, or sugar. After two minutes of exposure, radio-carbon tests showed that even proteins and fats already contained the new carbon just received from the atmosphere. The detailed investigations of these reactions are now in process and the full mechanism of this basic plant reaction should be understood very soon.

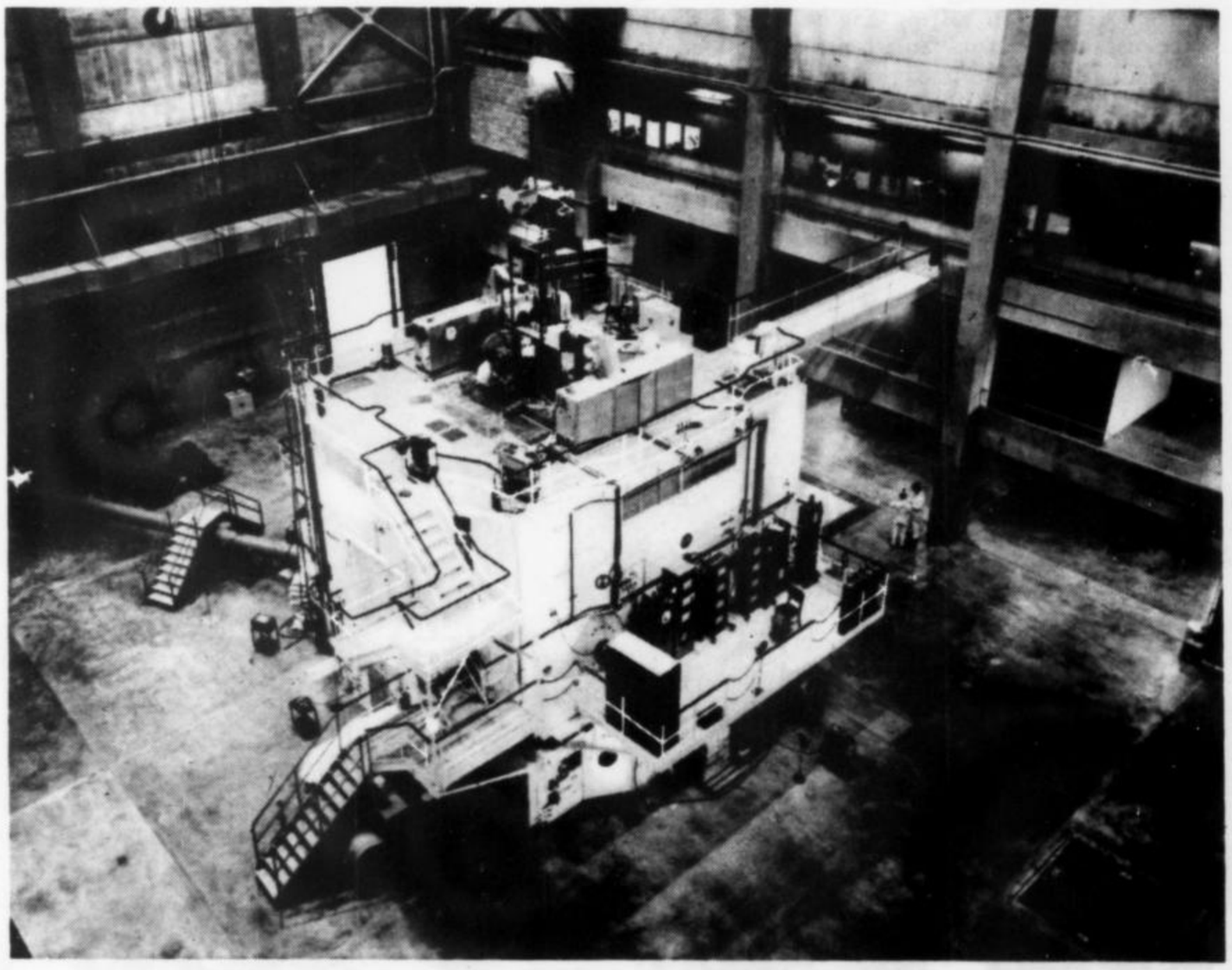
By studying the process in different plants it is now known that the early stages of the reaction are identical in all plants. Only later does the process diverge into the production of compounds that are characteristic of each plant, such as aromas, colours, and drugs. In the case of the green algae, it has thus been possible to divert the reaction among the algae so that either a preponderance of sugar or of malic acid can form early in the process.

$100 million saving

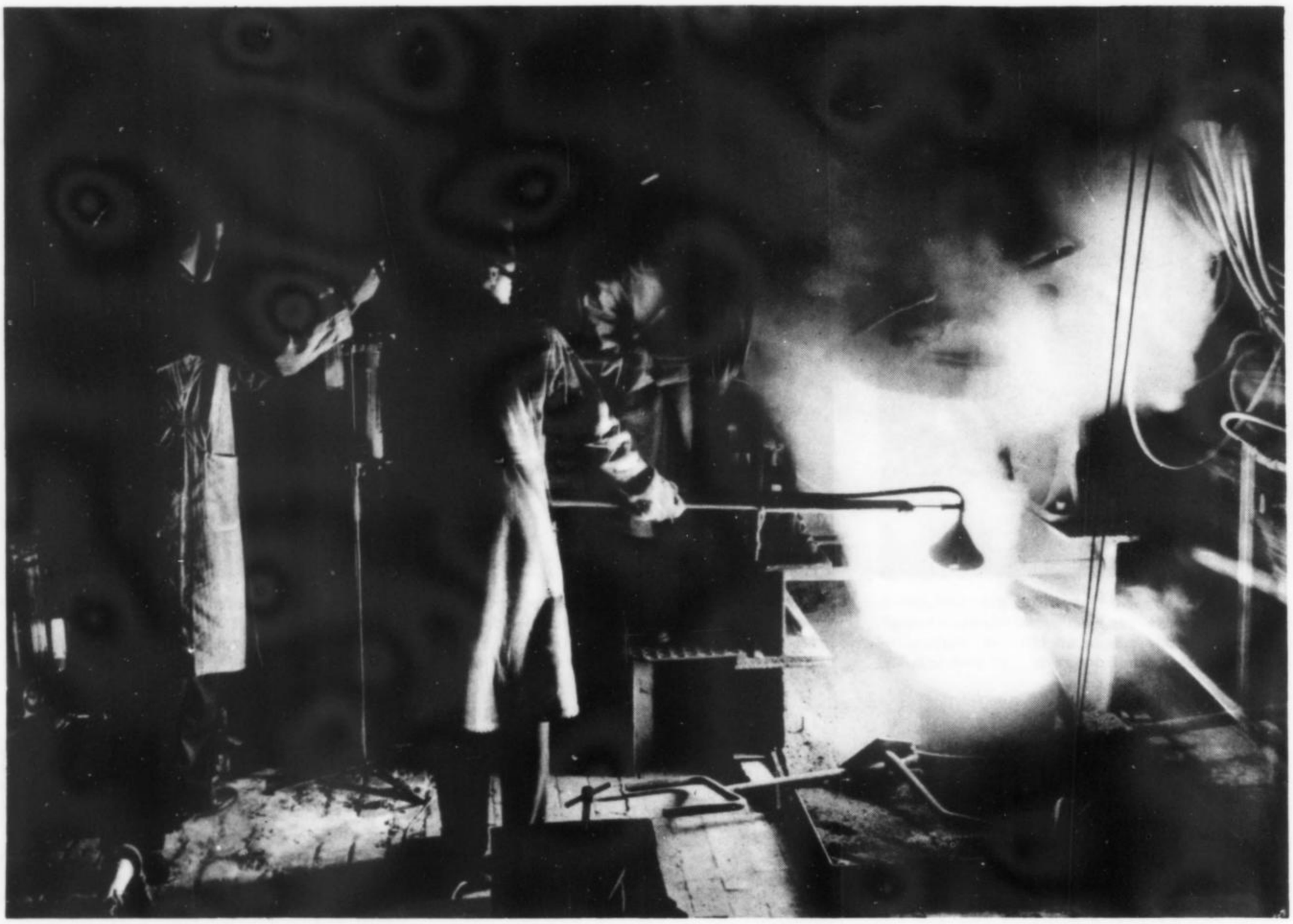
On this basis, the experiments have now been continued to show that the same algae which normally contain about 50 % of protein can be so altered as to produce about 75 % of fat instead of protein. In fact, the protein content can be varied all the way from 7 % to 88 %, while the fat content can be changed from 1 % to 75 %. At the same time, the carbon-dioxide can be changed from 6 % to 38 %. This obviously opens enormous possibilities for changing and increasing the food supplies available both to animals and to human beings.

These examples are only a few of the many thousands of uses of radio-isotopes in research, industry, agriculture and medicine. The U.S. Atomic Energy Commission estimates that the total savings accomplished by the use of isotopes in these various fields is more than $ 100,000,000 a year. Meanwhile, the sales of isotopes by the Commission amount to more than $ 500,000 a year. The European atomic reactors, especially those at Windscale and Harwell in England, are producing radio-isotopes that are sent all over Europe. Radio chemists at Amersham have achieved results which are distinctive and in some instances in advance of the American so that air shipments of isotopes across the Atlantic are now considerable.

As more reactors are installed and the use of atomic energy becomes general throughout the world the production of radio-isotopes will also increase with a resulting reduction in their price. One can be certain that the atomic age is only in its infancy and that in their impact on history the beneficial peace-time uses of the atom will far exceed their misuse in war.

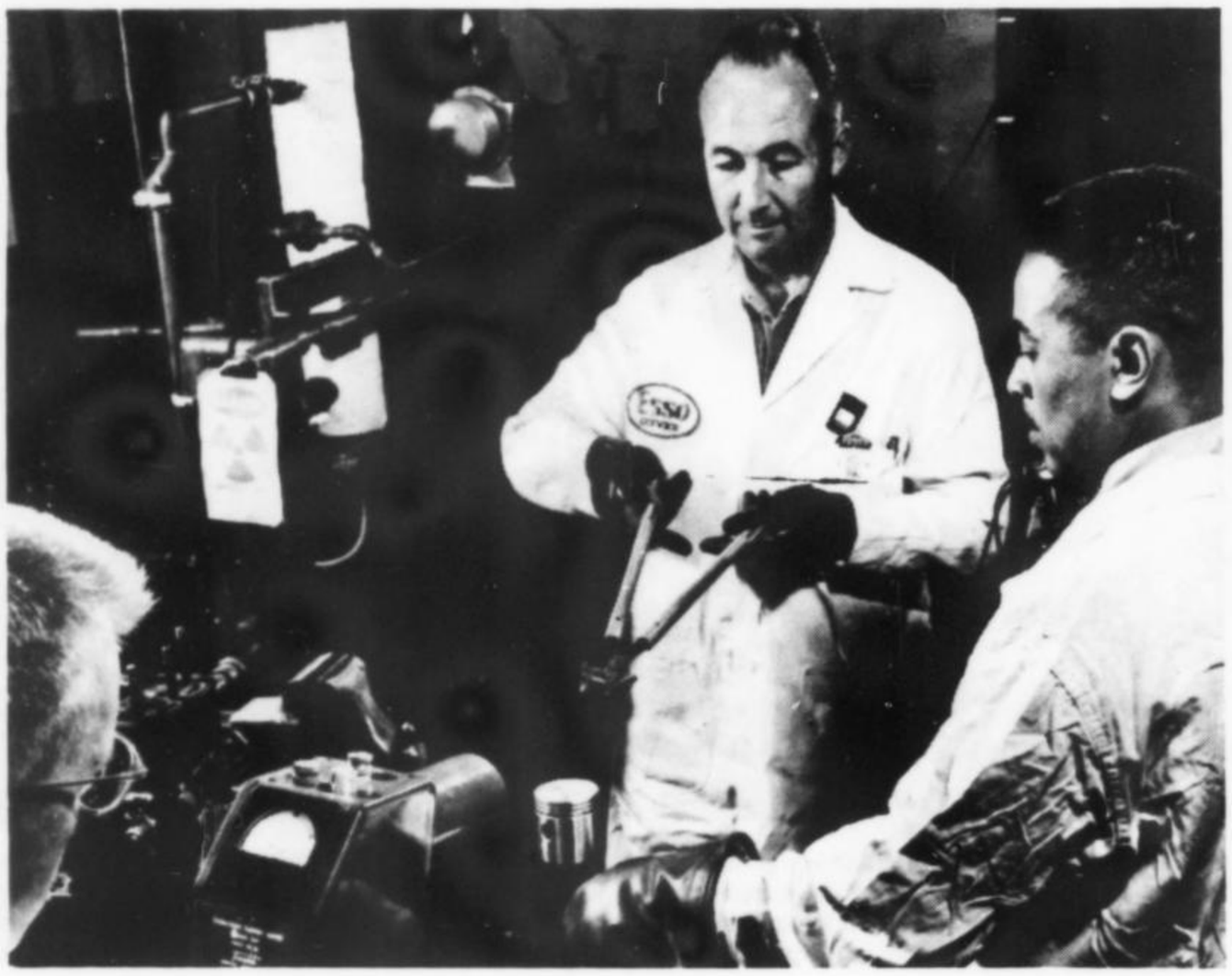


CONCRETE SHIELD weighing 3,000 tons is built around this materials-testing reactor in the U.S.A. Reactor, in the centre of a large room, is connected by a bridge to a nearby balcony from where it is operated by remote control. Thanks to concrete shield men around reactor and on upper platform are protected from radiation. (Photo USIS).



METAL PRODUCTION plant in Michigan, U.S.A. makes use of a large quantity of radio-active material for an industrial experiment. Radio-active powdered iron ore was mixed with ordinary powdered ore and fed into a blast furnace. Measurement of radio-activity from gases (shown here) helped technicians to decide on suitability of ore in powdered form for smelting iron.

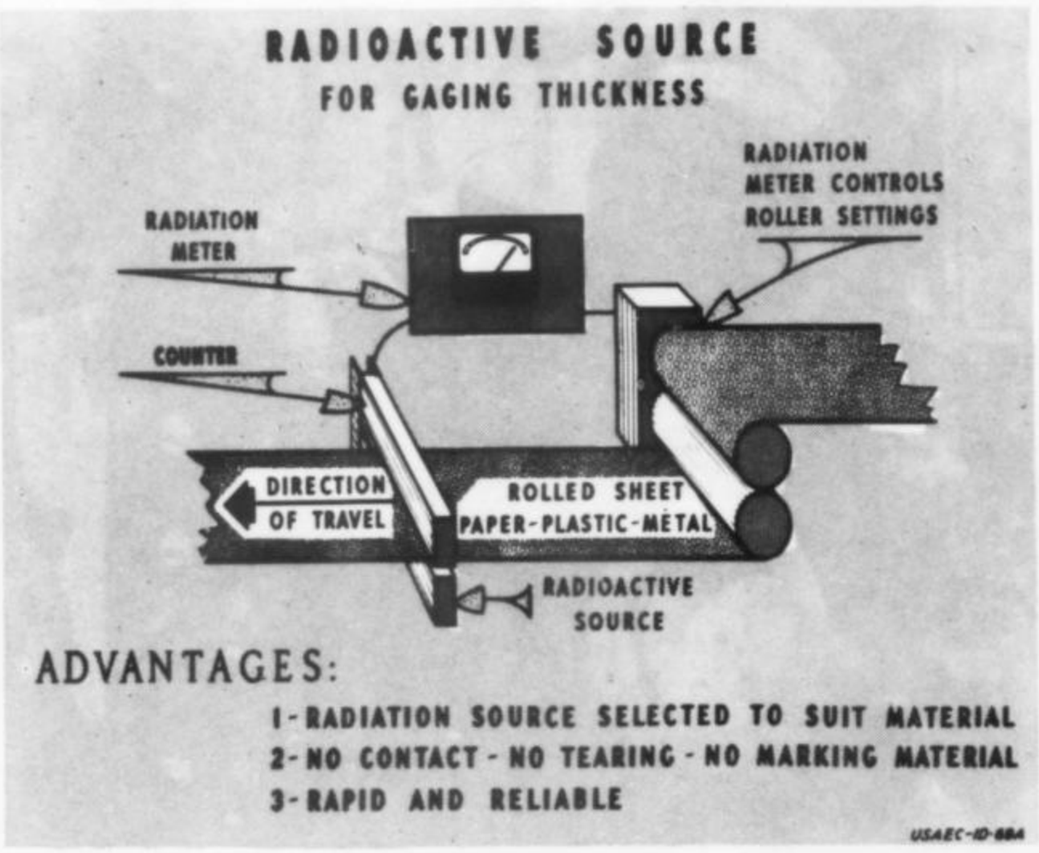
AUTOMOBILE MANUFACTURERS now save time and money by using radio-active materials in testing engine wear. Engine piston rings, made radio-active by exposure to reactor radiations, are placed upon a piston. The piston is run for several hours in a test engine, during which time some of the radio-active atoms are transferred to the lubricating oil. Periodic measurement with a counter shows how the metal wears and how the oil reacts to friction. (Photo USIS).

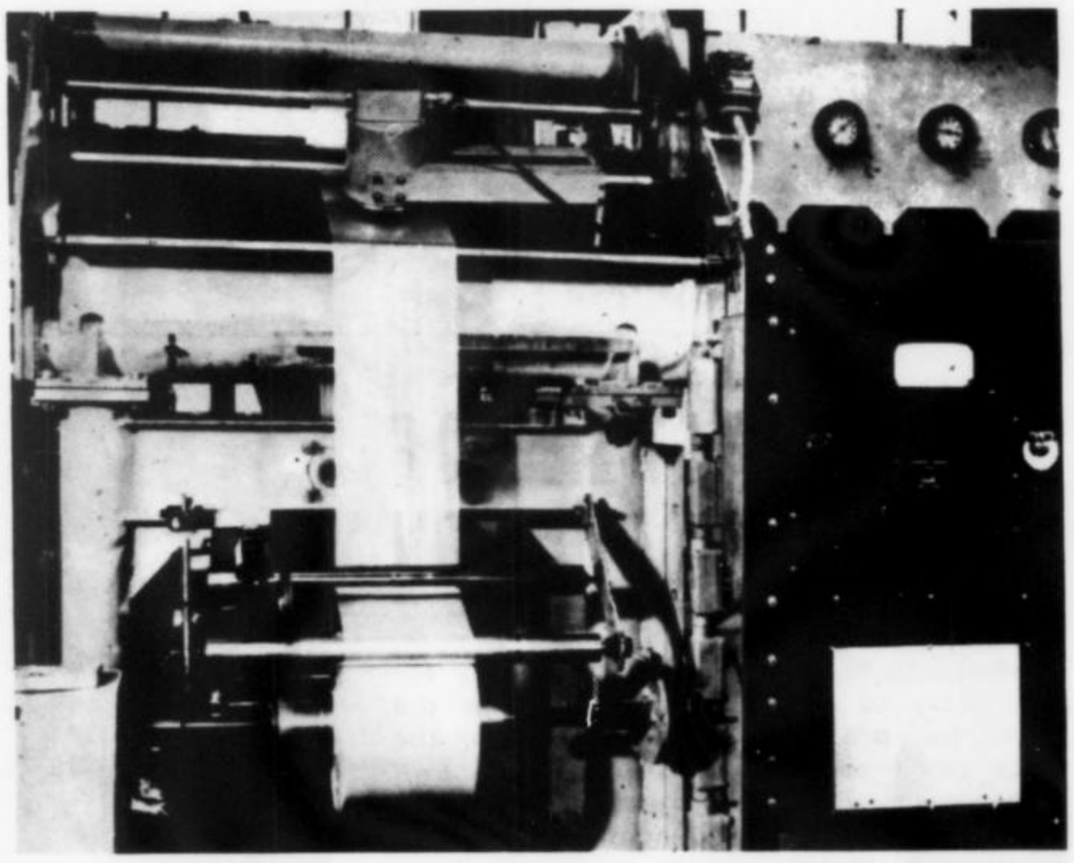


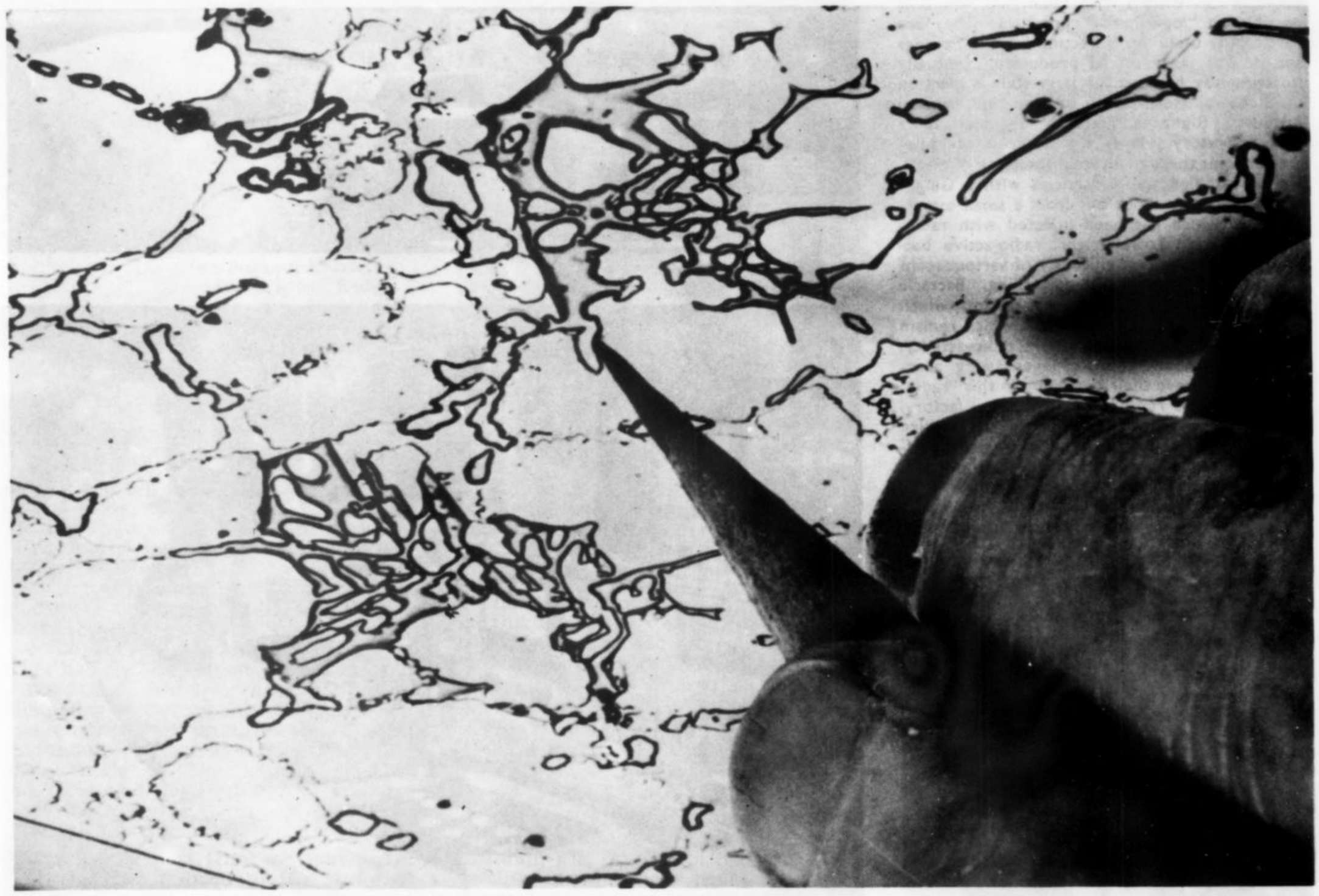
OIL INDUSTRY now uses isotope tracers to control pipe-line flow. Boundaries between different oils in same pipe are marked by small injection of radio-active chemical. Geiger counter at the receiving end shows exact division between two oils, so they can be switched to different tanks. (Photo USIS).

INDUSTRY'S NEW WORKER

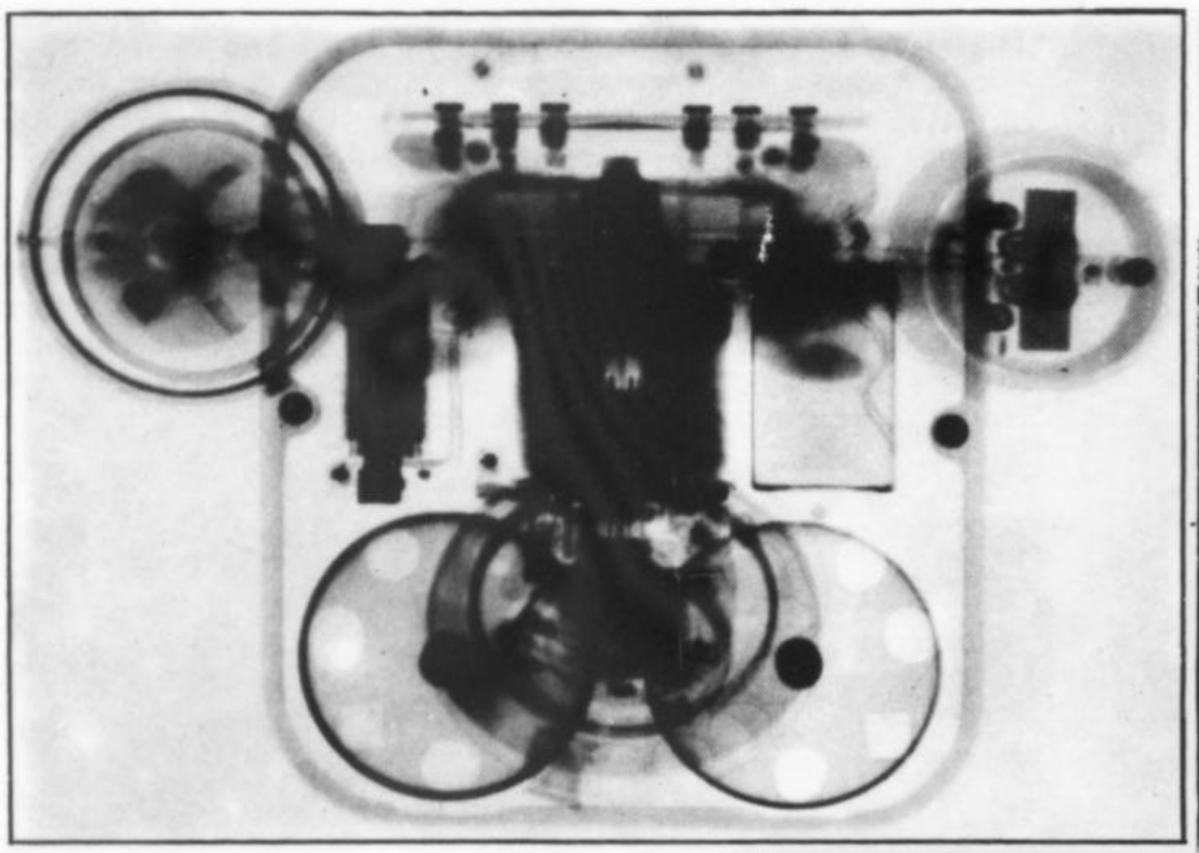
The magic of the atom is now serving many and varied industries. Radio-active materials are being employed in dozens of ways for testing and improving industry's products, making them faster and easier to produce. Safer drugs and medical supplies, better motor oil, better quality plastics, improved automobile tyres—these are only a few examples of improvements which atomic energy can contribute to progress in industrial development. As when primitive man first discovered fire and gradually learned to make its power serve him, so men of today gradually are learning how the power of the atom can be made to work for them.





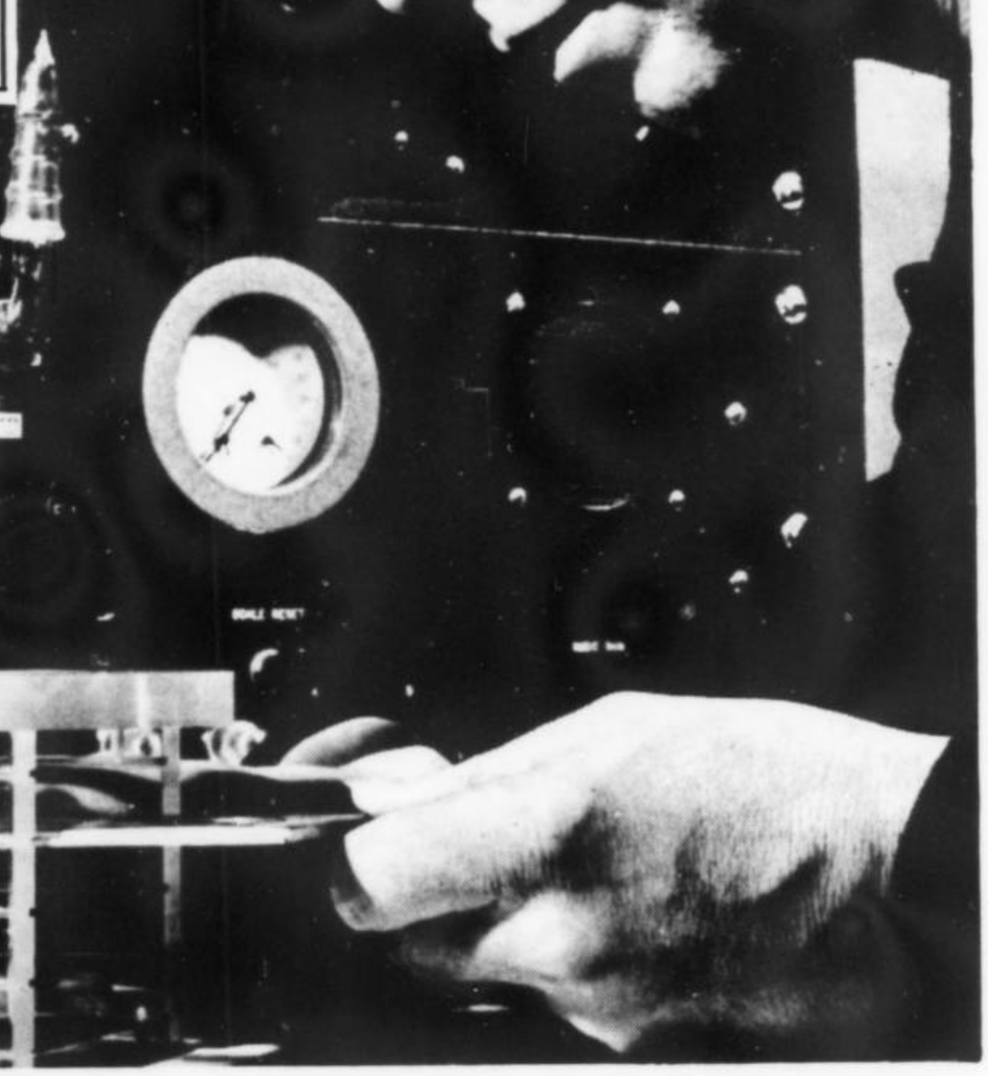


NEW METAL ALLOYS capable of great resistance to heat and corrosion are being sought by metallurgists to aid atomic energy development. Success of such research will bring benefits of atomic power more quickly to industry, and the new alloys will almost certainly find wide industrial uses. Photomicrography (above) of a uranium alloy is an enlarged picture of an etched cross-section of the metal from which a metallurgist can trace the existence of different physical properties (resistance to corrosion, mechanical behaviour etc) from local variations in the composition of the alloy. Pencil points to a new "phase"—a sudden appearance of new physical properties in an alloy produced by changes in the proportions of its chemical components. Such "phases" are clues which guide metallurgists in the production of alloys for special purposes. (Photo USIS).



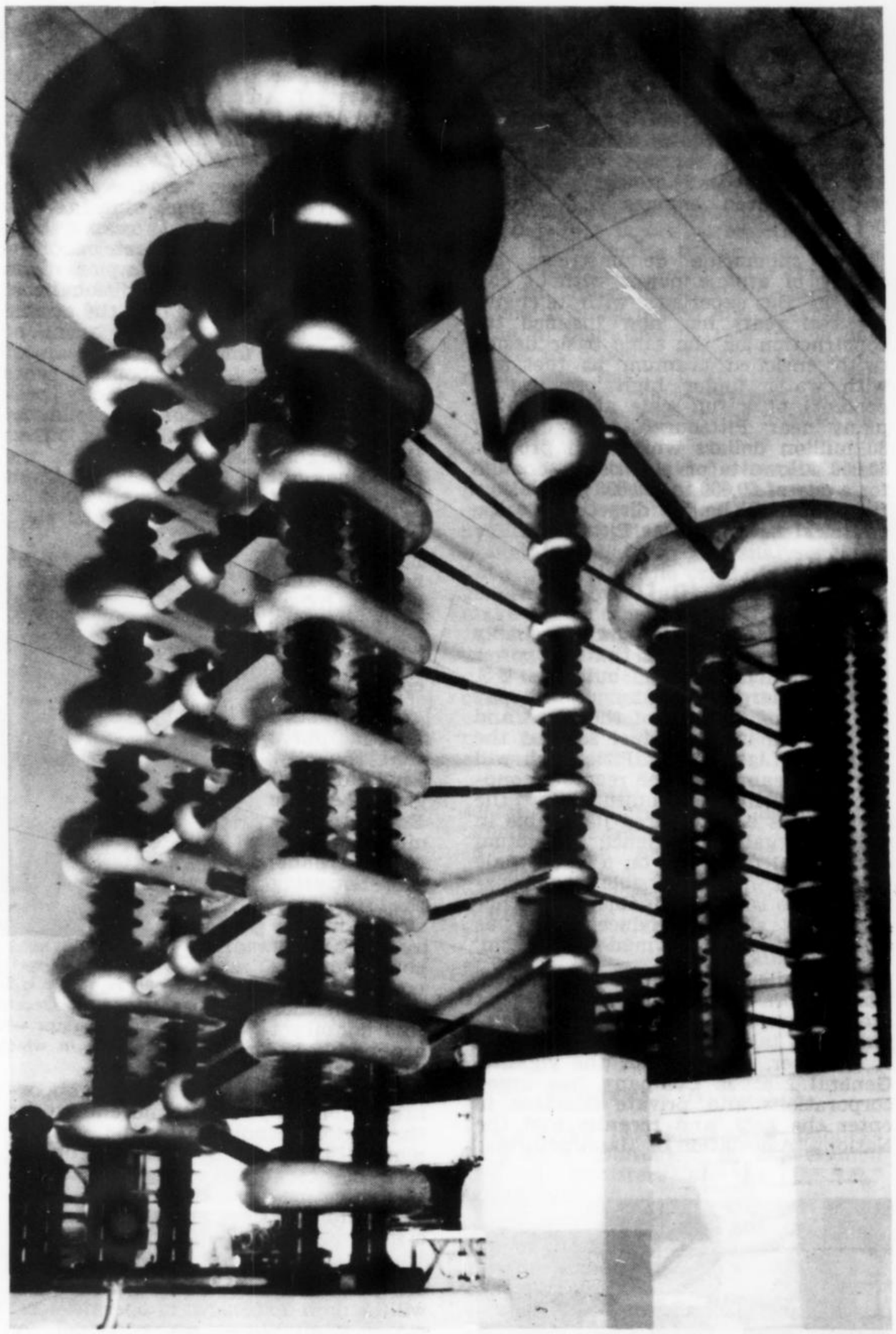
A BIRTHPLACE OF BETTER PRODUCTION

Laboratories and other research centres are the places to which industry looks for the answers to production problems involving the materials it uses. On this page are shown some ways in which technicians are using atomic energy to help improve industry's products. Radiographs, like the one above, of a telephone, taken in Gt. Britain with radio-gold, make it possible to "look inside" products. They are particularly useful for detecting flaws in castings and defects in industrial products. Eventually isotopes may be used for large-scale inspection of packages, sterilization of food and medical products. Right, a research engineer in a U.S. laboratory follows the progress of radio-active atoms through internal structure of metal. He counts high speed particles with a Geiger counter as they shoot out from a small sample of metal which has been injected with radio-active carbon. Lower right, radio-active bacteria are used to test efficiency of various soaps and detergents for washing clothing. Bacteria have been placed on small pieces of cloth which are then washed. Those bacteria which remain are easily detected by their radio-activity. Below, smoother-running, longer-lasting automobile parts have their beginning in this "radio-active materials room" at an American factory. Here, technicians are placing a radio-active distributor point into a standard engine distributor. After a test run, wear on the point can be measured from radio-active atoms which have been transferred to the distributor. (Photos Crown Copyright Reserved and USIS).



How Close Are We ?

NUCLEAR POWER IN INDUSTRY



AUSTRALIA is considering the development of a nuclear power industry. For fuel she has vast reserves of raw material in the form of uranium deposits. So far her universities have limited their research to studies of the atomic nuclei using such machines as the Cockcroft-Walton 1,250,000 volt multiplier in the Australian National University, Canberra (left). Recently, however, it was announced that a £12 million industrial nuclear reactor is to be built in South Australia, (Australian Official Photo).

IT is now ten years since the prospect of using atomic energy to develop power for light, heat and the work of the world began to intrigue scientists and governments alike. In 1945, when the world adapted once more to a relatively peaceful life, it was hoped that industrial atomic power would become a reality within ten years. This has not happened partly because international tensions have continued the policy of secrecy and partly because the engineering problems have been enormous. The great strides that have been made in the use of nuclear reactions and in the design of reactors have been by-products of the large expenditures for military purposes.

But in the past three or four years attention has shifted to the study of industrial power and to the economics of the use of nuclear fuels. There has not been time enough to provide experience for a realistic forecast in economic terms. There was, in fact, no great hope until the American breeder reactor in May 1953, first showed that common and cheap uranium and thorium can be used as fuels. That fact has greatly advanced practical industrial power from the atom.

The development has gone farthest in the United States because of that country's active development of reactors during the war and because of the large economic resources it had available after the war. Even there, however, there is as yet no operating atomic power reactor for industrial purposes.

The U.S. has constructed more than a score of major reactors, some for the manufacture of plutonium and uranium-235, some for the intensive testing of materials that are to be exposed to atomic rays, some to test the principle of breeding and most of them to test the feasibility of different types of reactors, operating on different fuels, with different intensity of neutron bombardment, with different methods of cooling and other modifications.

In one type, for instance, the fissionable uranium is dissolved in water and the heat of fission causes the water to boil and generate steam directly. In another type the uranium is dissolved in metallic bismuth. Such experiments will continue, but they have already produced actual designs for two full-size power reactors.

The first of these has been installed in a new type of submarine which depends wholly on atomic energy for its motive power, and which was launched on January 21, 1954. It extracts from a small piece of atomic fuel the equivalent of 460,000 gallons of fuel oil or 3,000 tons of coal. Considerations of cost have not entered into its construction because the advantages of an atomic engine outweigh the cost.

The submarine can cruise for an indefinite period of time under water because its engines need no air. It

The world atomic power picture

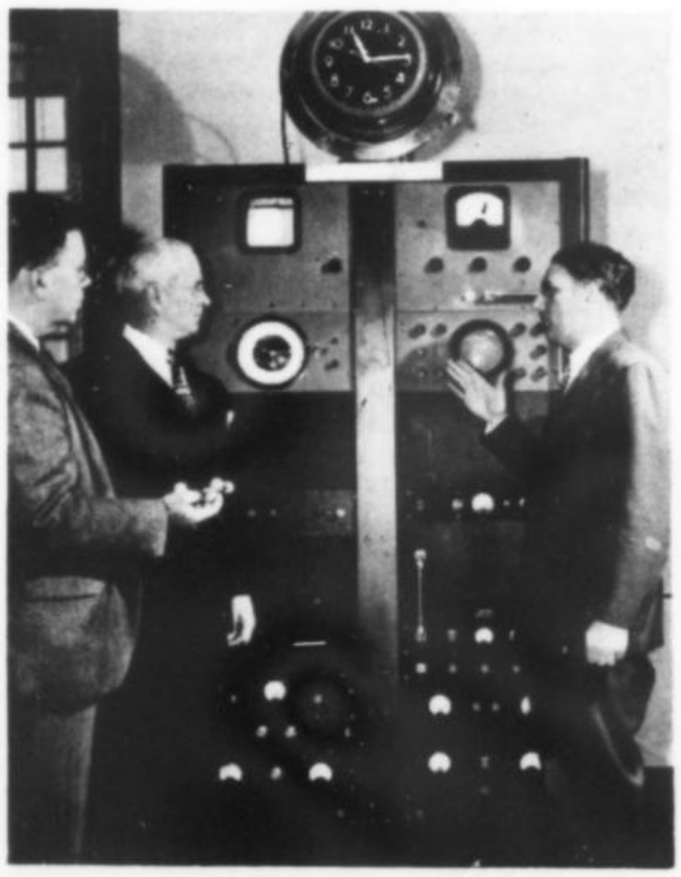
does not need to return for refuelling because the charge of atomic fuel will propel the ship for any voyage. The keel for a second atomic submarine with improved engines has already been laid.

The submarine demonstrates the reality of atomic power without cost figures. But experience with its engine for two years has now justified the construction on the same basic design (with enriched uranium as fuel and with water under high pressure as coolant) of a full-scale atomic power plant near Pittsburgh at a cost of 30 million dollars which will produce 60,000 kilowatts of electricity—enough for a city of 60,000 to 100,000 population. Its power will be fed directly into the electrical network near Pittsburgh.

Optimism in the U.S.A.

THE cost of its power will probably not be as low as that of power made from coal, but the U.S. Atomic Energy Commission will pay five-sixth of the cost of the plant and provide the uranium fuel so that the Duquesne Light Co. of Pittsburgh will buy the steam from the reactor economically. This expenditure by the government is considered justifiable in order to gain experience in actual commercial operation on a large scale which will make possible the construction as soon as possible of another plant that should produce power as cheaply as it can be made from coal.

Meanwhile, the American technical world is fascinated by a variety of atomic projects, with the electrical industries taking the lead. Mr. Ralph J. Cordiner, President of the gigantic General Electric Company has urged corporations and private business to enter the field, and recently told the National Association of Manufacturers:



ATOMIC AGE CLOCK built by the National Bureau of Standards, Washington, would require at least 3,000,000 years to lose or gain one second. Scientist on extreme left is holding a model of the ammonia molecule whose absorption of radio energy provides the invariant frequency on which clock is based.

"It is our optimistic estimate that by 1976, 50 % of the new electric power facilities being installed will be atomic."

General Electric engineers have recently calculated that while a coal-burning electric plant costs about $130 per kilowatt of electrical productive capacity, an atomic plant costs from $195 to $215. This additional cost is balanced by the fact that the atomic fuel cost, including the processing of the uranium and the disposal of chemical wastes, is only about 0.1 cents per kilowatt hour of electricity produced, while the coal cost for a plant of similar size is about 0.35 cents. Thus the saving in fuel makes up for the additional cost of the atomic plant and the total cost of electricity from the atom is 0.67 to 0.68 cents a kilowatt hour compared with 0.69 cents for that from coal.

It is in such an atmosphere that the New England Regional Atomic Energy Committee has been organized, covering the six small states in the northeastern corner of the country, which have neither coal nor oil yet are highly industrialized. Its purpose is to take the first opportunity for adopting atomic energy for the region. Similarly in the western mountain state of Colorado a group of four co-operatives engaged in rural electrification have begun a campaign to obtain the first atomic reactor for a small electrical station.

ELECTRIC BULB was lighted for the first time by atomic energy at the U.S. Atomic Energy Commission's testing station in December 1951. An atomic plant powers the generator which supplies all the electricity for the building in which it is housed. (Photo USIS).

The attractive calculations of costs are based on large plants; small ones will be more expensive to operate. Yet many small plants are proposed for special purposes. For instance, an able physicist, Dr. Lyle B. Borst, of the University of Utah, has published designs developed in co-operation with five railroad and nine manufacturing corporations, for an atom-powered locomotive with 7,000 horse power and a length of 160 feet. It would cost $1,200,000 but its reactor, of the water boiler type, would use only 11 pounds of uranium in a year's operation.

In France, Mr. Louis Armand, Director-General of the French Railway System, has commented that it would be wiser to use a reactor to provide power directly to the electrified railroad system. This is true where such a system exists, as in France and Switzerland, but the great distances and lack of electrification in other countries make the nuclear locomotive a real possibility.

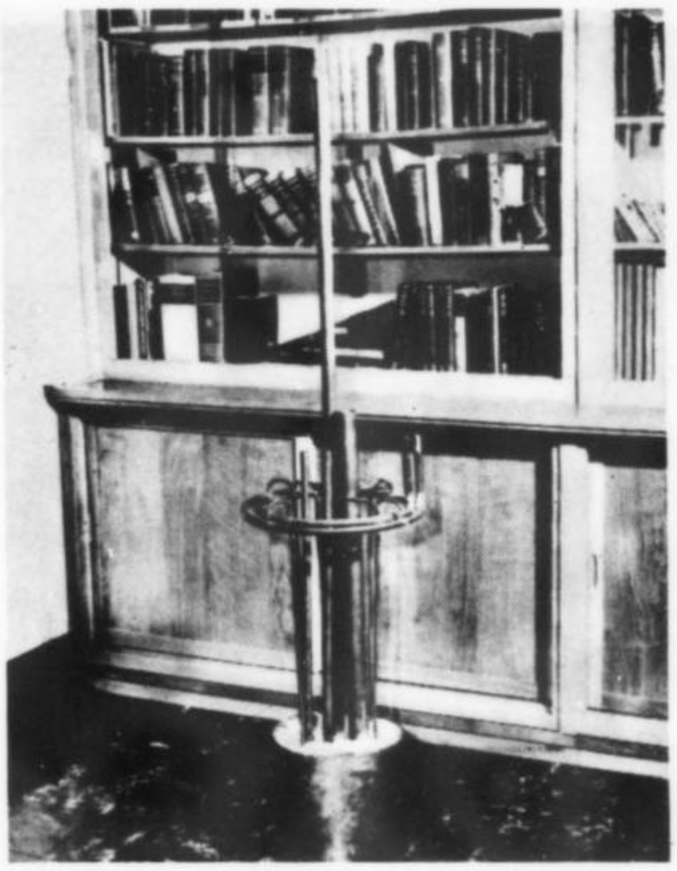
For other isolated stations that require power the U.S. Army has already awarded a contract for the design and construction of a 2,000 kilowatt nuclear-power, plant to cost about $2,000,000 which is to be so constructed that none of its constituent parts is too large or heavy to be carried by airplane. A plant of that size would be adequate to serve a community of 2,000 persons and could be carried intact to outlying military posts, such as those in the Arctic, to provide power, light and heat.

This is what has been called the "package power reactor", referred to by M. Jules Moch before the U.N. General Assembly. (See page 13.) If it is successful it may well be a model for the small reactors in many countries. It could, for instance, be flown to desert areas to serve pumps for irrigation from underground streams, or to coastal deserts for the production of fresh water from the sea. The international atomic energy agency will probably stimulate such uses.

The 220 pounds of atomic fuel that the U.S. has promised to provide through the international agency, plus the 44 pounds offered by the British Government, would be sufficient to provide fuel for some 15 research reactors in different countries.

The U.S. Atomic Energy Commission is continuing its expensive researches into still newer types of reactors and has authorized the construction of five in addition to the score already in operation. They are of two major types, one of which uses water as the coolant and the other liquid metal. Among them are the "homogeneous" reactor in which the fuel is dissolved in a liquid that acts both as moderator and as coolant and the "fast breeder" reactor which is compact and operates at high temperature. The investment of many millions of dollars by the government in a wide variety of experimental reactors is expected within a few years to result in a practicable, reliable and economic design for industrial reactors.

The Chairman of the Atomic Energy Commission, Admiral Louis S. Strauss has recently said "Our children will enjoy in their homes electrical energy too cheap to meter". He has also said that by a conservative estimate, only five years from now 10 % of the new American power plants will use atomic energy instead of coal, oil or gas and that by 1980 half of them will do so. Such optimism is impressive because it is made in a country where coal, oil and natural gas are all plentiful and cheap and where atomic fuels face severe cost competition. One may conclude that in countries where these ordinary fuels are expensive or must be transported over long distances the atomic age cannot be far off.



POCKET REACTOR was built by the North Carolina State College, U.S.A. to train engineers in the use of atomic energy. Reaction, obtained from uranium-235 contained in the cylinder, starts when two of the rods in the can are lifted by remote control.

Canadian atomic research and production have been closely related to that of the United States for more than ten years, especially in the production of uranium ores and the manufacture of uranium. Aside from a pilot model, the only Canadian reactor is a large one at Chalk River, with an energy-output of 30,000 kilowatts and a neutron flow of 60 million million neutrons per square centimeter. It has probably been the world's most powerful reactor using natural uranium, and produced large quantities of highly active radio-isotopes for use in commerce and research. It was in operation for more than five years, from 1947 to 1952 when it was taken apart for repairs after an accident.

A second large reactor, now being built and due for completion in 1955, will cost more than $30,000,000. It will be more powerful than the first, will use heavy water as a coolant and is designed to permit nuclear engineering studies for a future power-producing reactor. Three large Canadian electric power companies and the Ontario Hydro-Electric Commission are associated in the project, though it is controlled by a crown corporation, Atomic Energy of Canada, Ltd. This is in the expectation that future atomic power generators should be in the hands of the producers and distributors of electric power.

Confidence in Britain

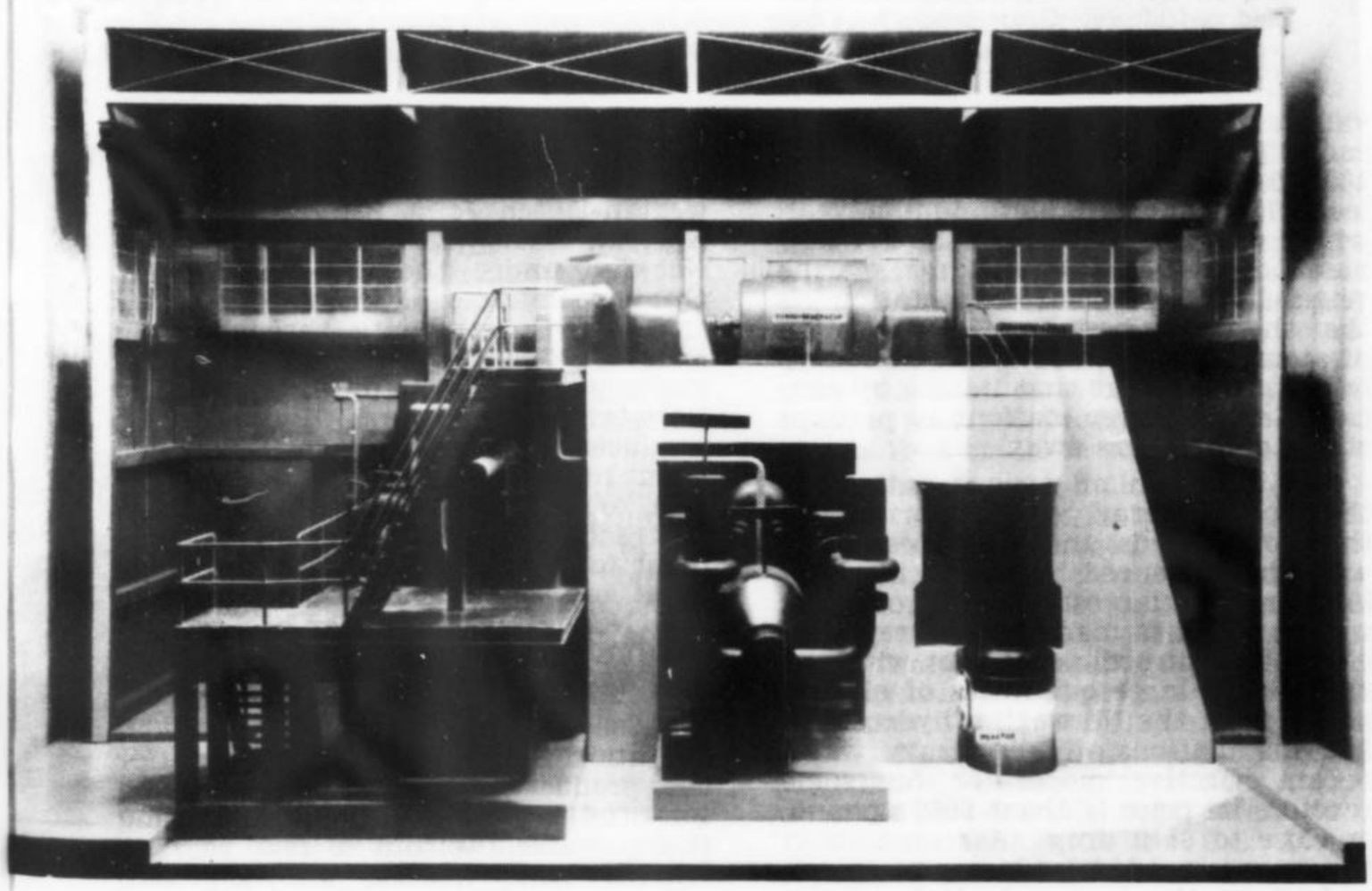
THE development of atomic power is more urgent in Britain than in the U.S. or Canada because the exhaustion of easily workable British coal mines is already noticeable. As a result the cost of coal is slowly increasing and it is officially estimated that there may be a deficit of twenty million tons in the British coal supply by 1965.

Work on atomic energy did not begin in England until 1946, however, all British efforts having been combined with those of the U.S. and Canada in North America during the war. That year saw the beginning both of the research station at Harwell under the direction of Sir John Cockcroft and the production division, with headquarters at Risley, under Sir Christopher Hinton. The first research reactor was built at Harwell while a plant for the manufacture of uranium from Australian and African ores was built at Springfields. Two reactors, side by side, for the production of plutonium from uranium were begun at Sellafield on the Cumberland coast in 1947.

By May 1953, confidence in the possibilities of power production was sufficient to justify the start of a full-scale industrial power reactor at Calder Hall, adjoining the Sellafield plant. It is now in construction and is expected to be in operation in 1956. It is designed to produce 50,000 kilowatts of power and has a distinctive cooling system which utilizes carbon dioxide under pressure to carry the heat to the steam boilers.

It will probably be the world's first large-scale power reactor to reach the operating stage. No cost figures are available but Sir Christopher Hinton has stated that "a cost analysis does not suggest that the price of electricity generated from atomic energy will make it uncompetitive" with electricity from coal. And the British scientific weekly, *Nature*, has expressed the opinion that "by the time such a station could be brought into operation, technical and economic developments would give nuclear power very considerable economic advantages."

A breeder reactor has been in research operation at Harwell for some time and the construction at Dounreay, in Caithness, Scotland, of a large breeder reactor, which should greatly reduce costs, has been authorized. In justifying the government plans, Sir David Eccles, Minister of Works, emphasized the need of training men who would design, construct and operate reactors not only for Britain and the Commonwealth but for friendly countries the world over.



PACKAGED POWER PLANT: An exhibit on the Peaceful Uses of Atomic Energy, prepared by the United States Government, has recently been on display at United Nations Headquarters in New York. Taken from the exhibition is this model of a "package" atomic power plant. Broken down into sections, it could be taken by air to a remote site where regular fuels are unobtainable or too expensive to transport. The plant could provide electricity for a mining community or pump water to arid zones, and a single plane could carry enough atomic fuel to run it for several years. (U.N. photos.)

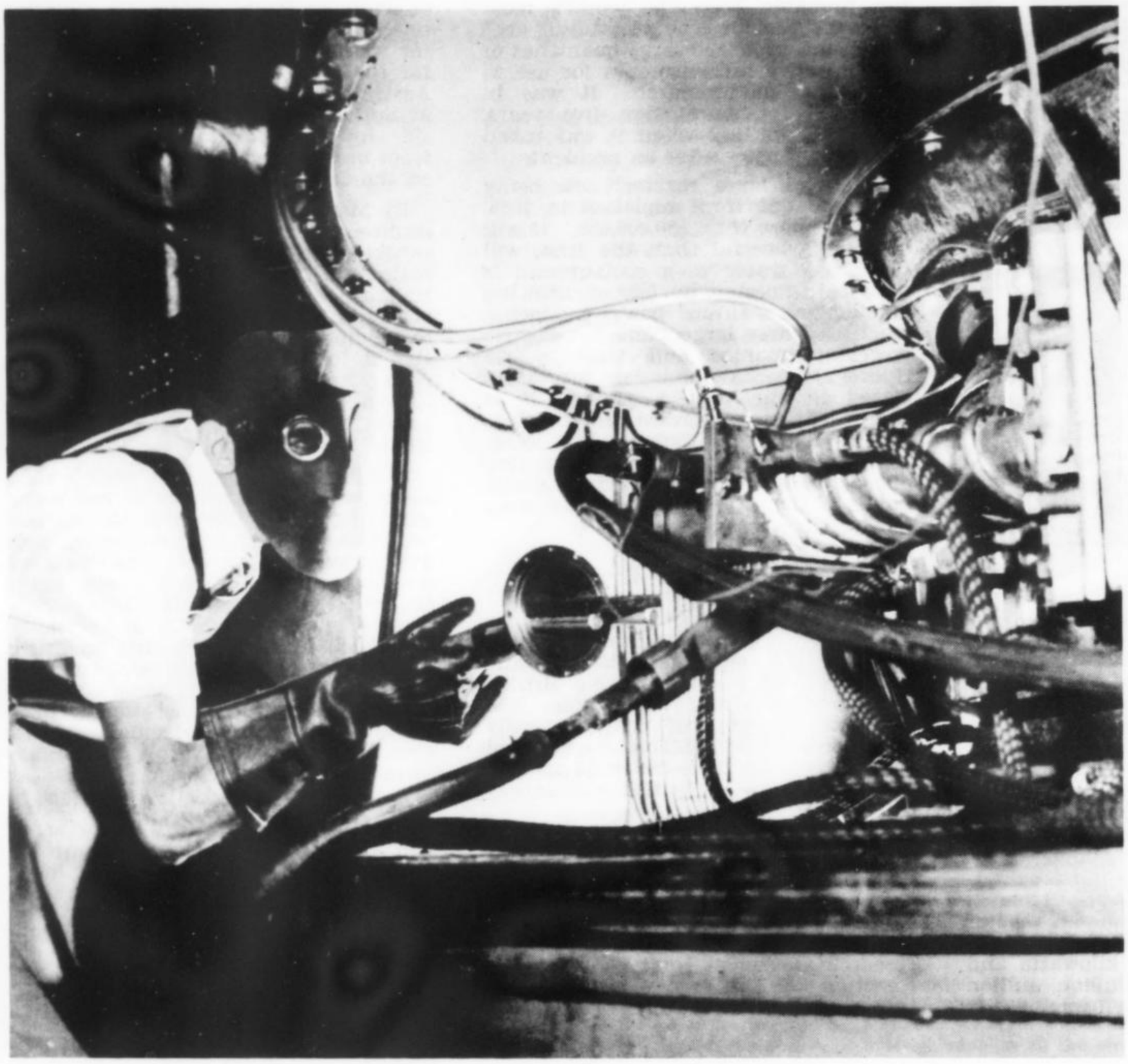
Progress in Russia

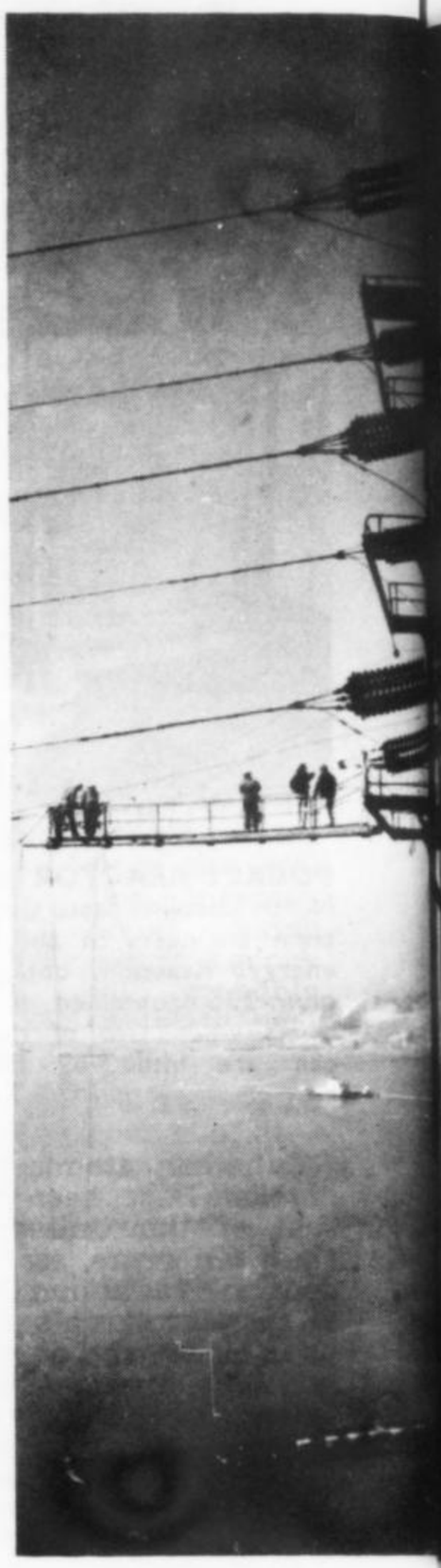
ON July 2, 1954, *Soviet News* published a "Statement by the Council of Ministers of the U.S.S.R." which read :

"Work on the design and construction of the first industrial power station run on atomic energy, with a useful capacity of 5,000 kilowatts, has been successfully completed in the Soviet Union, by the efforts of Soviet scientists and engineers. On June 27th, 1954, an atom-driven power station was put into operation and generated electricity for the use of industry and agriculture in the neighbouring districts. For the first time an industrial turbine is working, not on coal or some other fuel, but on atomic energy—the product of fission of the nucleus of the uranium atom. By putting the atom-driven power station into operation, a real step forward has been taken in the utilization of atomic energy for peaceful purposes."

Speaking to the "First Committee" of the U.N. General Assembly on November 12, 1954, the Soviet delegate, the late Andrei Y. Vishinsky, repeated this announcement and added:

"There are no obstacles in the Soviet Union to the further successful and rapid progress along this path of utilization of atomic energy for peaceful purposes and the implantation of these methods throughout our economy... The Soviet Union State, which has broad facilities for the extensive pro-





IMPRESSIVE PROGRESS has been made during the past ten years in applying the forces of nuclear fission to peaceful and constructive uses, thus opening up to our own future generations an ever-expanding prospect of material betterment. After having been rendered radio-active in nuclear reactors (above, left), isotopes have been put to work on a thousand tasks for medicine, industry and agriculture. Great strides have been made in the design of reactors and in the use of nuclear reactions. More than a score of major reactors, such as the one at Brookhaven National Labo-

duction of atomic energy, is profoundly interested in the utilization of this new type of energy for peaceful purposes and for the well-being of our people because this kind of utilization of atomic energy, by countries which are prepared broadly and extensively to use it for peaceful ends, would open wide, tremendous prospects of a vast growth of productive forces, technological and cultural progress, and the increased well-being of society."

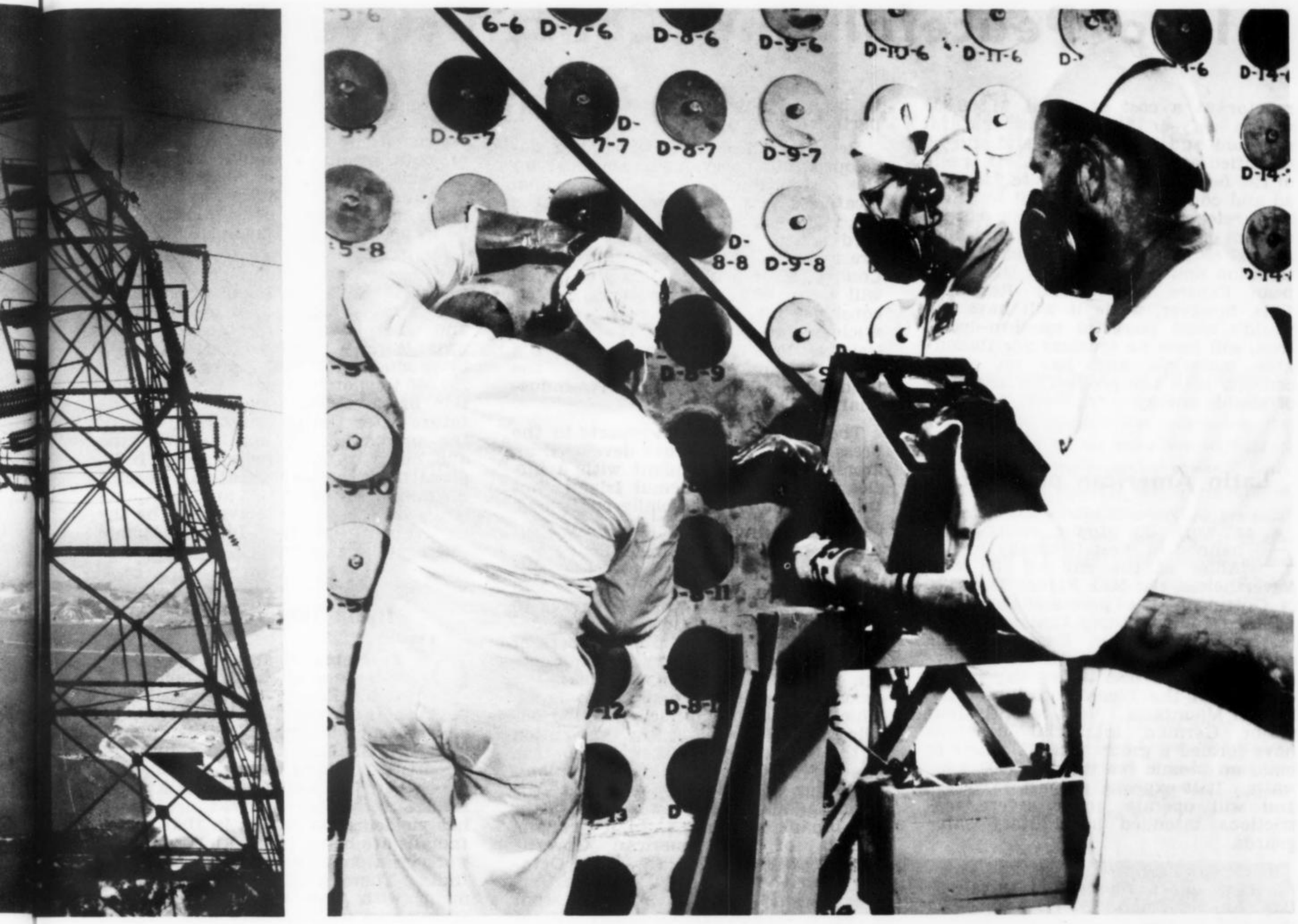
The historic succession of distinguished research physicists in France, and the fact that France itself has large uranium deposits and very large deposits of thorium in Madagascar plus its diminishing coal reserves, have all been factors in the French atomic energy programme. A small research reactor was established at Chatillon, a suburb of Paris in 1948. A second, larger one at Saclay, near Paris, has been in operation since 1952, using pure metallic uranium in a moderating bath of heavy water. It was designed for an energy output of 1,000 kilowatts but delivers more, and may be improved to reach 2,000.

A pilot plant in the Rhone valley for a reactor that will produce 50 to 100 grammes of plutonium per day has also been planned. This is preliminary to the construction, also in the Rhone valley, of two large reactors that will each generate between 50,000 and 100,000 kilowatts and will produce at least 75 pounds of plutonium a year, which will, in turn, permit the development of nuclear engines for marine vessels. The official expectation is that there may be industrial utilization of atomic energy in France within four to eight years, but that its use by central electric power stations is perhaps still a dozen years away.

The approach of various nations to the atomic energy problem varies with their own needs and resources. Norway's is influenced by the fact that it is the world's largest producer of heavy water, which is made by the repeated electrolysis of ordinary water with the use of very large quantities of electric power from the Norwegian hydro-electric installations. While heavy water is an effective moderator for some reactors its price is about $560 a pound, or close to $1 a drop. A reduction in the price is needed for larger-scale use, and Switzerland, Israel, Italy, India and New Zealand have all been considering its production.

In 1951, Norway had under construction a reactor to use its heavy water, but it had no uranium. Meanwhile Holland had several tons of uranium on hand that had been farsightedly purchased when uranium fission first became a possibility. The two Governments therefore organized the Norwegian-Dutch Joint Establishment for Nuclear Energy Research at Kjeller, Norway, under the direction of Dr. Gunnar Randers. It is supported by the two Governments through their Research Councils and scientists of the two countries work side by side. The Norwegian firm, Norsk Hydro, which produces the heavy water, supplied about half the money for the construction of the first reactor and has a contract with the Norwegian Government for further work on the development of atomic energy. Both Dutch and Norwegian industries are supplying funds and obtaining rights for future energy exploitation.

A 300 kilowatts reactor has been in operation for almost three years for the production of radio-isotopes and for studying the feasibility of using heavy water. Within a few years a reactor using natural uranium with heavy water as the moderator will be built to produce steam at about 250 degrees centigrade and to give from 5,000 to 10,000 kilowatts of power. Dr. Randers, speaking before the Economic Society of Norway recently, stressed his opinion that without the use of atomic energy as a source of



ratory, from which workers are shown removing "spent" uranium (above, right) have been built in the United States. But in the past four years, attention has shifted to the study of industrial power. Here again, so much progress has been made that authorities in the United States have declared that in twenty years time half the new electric power facilities then being installed will be atomic. Scientists say this is only a beginning. They believe the use of atomic energy materials will increase tenfold or more in the next few years. (Photos Edison Electric Institute and USIS.)

power, the world's population will by the end of this century be faced with a power deficiency that will lead to stagnation or to a lowering of the general standard of living. In England Josiah Eccles of the British Electricity Authority made a suggestion pertinent to Norway—that countries with surplus hydro-electric power should use it to concentrate and purify fissionable fuels such as uranium for export to regions with power shortages.

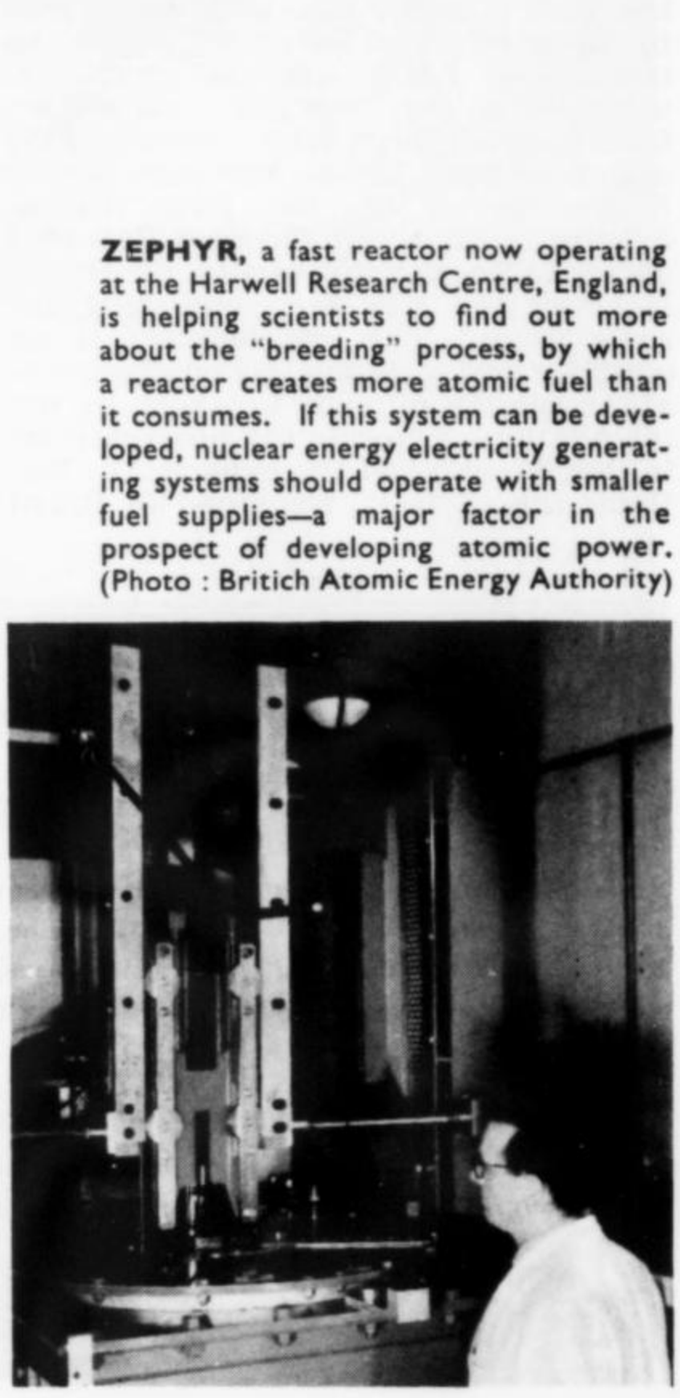
Sweden has been producing uranium for some time and is now increasing its production from the deposits of oil shale at Karnstorp which contain lumps of kolm, a hydrocarbon that contains as much as 3,000 grammes of uranium per ton. Sweden has one small reactor of 100 kilowatts capacity which uses three to four tons of uranium. It is built in Stockholm in a special underground chamber hewn out of bedrock. A 10,000 kilowatts reactor is to be built by A.B. Atomenergi Co. of which the Government owns 57% and fifteen private firms own the remainder. Officials do not believe that atomic energy will be competitive with water power in Sweden until all the nation's hydro-electric sources have been put to use, which will presumably be in about twenty years.

Belgium has long been the world's major producer of uranium from its great Shinkolobwe mine in the Belgian Congo. The uranium has been shipped in large quantities to the United States since 1944 under a ten years contract. Negotiations on this question have been going on between the Belgian and U.S. Governments. Belgium wants to receive technical information on the peaceful uses of atomic energy and nuclear material produced in American plants that could be so used.

Belgium is now building an experimental reactor at Mol intended primarily to train personnel and secure operating experience. It should be in operation early in 1956, providing 2,000 kilowatts of power. This reactor is being financed "without intervention of the Treasury or of private industry, in accordance with arrangements of an international nature", said Pierre de Ryckmans, Commissioner for Atomic Energy. Presumably this refers to a new agreement with the U.S. Atomic Energy Commission.

Belgium has also signed an agreement with the Swiss Government whereby small amounts of uranium from Belgian ores will be supplied to Switzerland along with the exchange of information and experience in the operation of reactors. The Swiss expect to begin construction of a power

ZEPHYR, a fast reactor now operating at the Harwell Research Centre, England, is helping scientists to find out more about the "breeding" process, by which a reactor creates more atomic fuel than it consumes. If this system can be developed, nuclear energy electricity generating systems should operate with smaller fuel supplies—a major factor in the prospect of developing atomic power. (Photo : British Atomic Energy Authority)



'...Into Peaceful and Constructive Paths'

reactor at a cost of about $4,500,000 within a year. It will use natural uranium and heavy water and will be classified at 10,000 kilowatts. It is one of the few that will be privately financed and controlled, being built by three Swiss electrical manufacturing corporations. In Geneva, Switzerland also is host to the large new research installation now being built by the European Centre for Nuclear Research. This, however, while it will have the world's most powerful synchro-cyclotron, will have no reactors nor fissionable materials and has no direct concern with the production and uses of atomic energy.

Latin American prospects

All work on atomic energy was banned in West Germany by the Allies at the end of the war. Nevertheless, the Max Planck Institute of Göttingen has processed and distributed radio-isotopes that are flown in from Harwell in England. The mining of uranium, with Allied permission, is now also under way in the deposits in the Black Forest and the Fichtel Mountains. Very recently four major German industrial concerns have formed a group with 12 others to build an atomic reactor of 10,000 kilowatts. It is expected to cost $5,000,000 and will operate under severe restrictions intended as military safeguards.

There are as yet no reactors in Latin America, but a representative of the U.S. Atomic Energy Commission has reported on the basis of an extended trip that uranium is as plentiful as lead in much of Latin America's subsoil so that some Latin America countries, using their own uranium, can expect to base their industrial revolution on atomic power. Brazil, however, has at Niteroi, across the bay from Rio de Janeiro, a Centre of Physical Research attached to the University of Brazil. Its cyclotron has been operating for some years. This development is an outgrowth of a United Nations Technical Assistance mission to assist in the installation of cosmic ray observatories in Bolivia. One of the experts, Dr. Ugo Camerini, of Italy, remained in Brazil to become chief of the Centre's department of physics.

Recently these nuclear studies developed into government approval for the establishment of an uranium treatment plant at Pocos de Caldas, a spa in the state of Minas Gerais. According to Admiral Alvaro Alberto, President of the Brazilian National Council for Scientific Research, work will begin within three years on the construction of a pilot reactor to use nuclear fuel produced at Pocos de Caldas. This is the first step toward a later Brazilian programme for the production of atomic power for industrial use.

There have also been reports in the press that Argentina has developed an atomic energy pilot plant with a nuclear reactor at Huemul Island, but this has not been officially confirmed.

One of the major problems of the international atomic energy agency will be the assignment of priorities for atomic power development. This will involve large decisions of policy as to need and successful prospects of development but one of the members of the U.S. Atomic Energy Commission, Mr. Thomas E. Murray, is already on record as favouring a priority to Japan which as yet has no nuclear power developments. Speaking to a Convention of the United Steel Workers of America, one of the major labour unions, Mr. Murray recommended that the building of a nuclear power plant in Japan should be high on the agenda of the American Government. He was speaking in October prior to the discussion of the United Nations Agency. He urged that America should express its intentions and must "give by action and not by words alone clear and tangible proof of our own determination to channel the energy of the atom as soon as possible into peaceful and constructive paths".

India is rich in nuclear raw materials in the enormous deposits of monazite sand on the shores of Travancore. These deposits contain at least a million tons of thorium in a form that is easily extracted, and widely scattered minerals of uranium. The Government is so conscious of the value of these materials for India's future as an industrial country that the export of thorium and uranium ores, as well as those of beryllium, has been sharply restricted. A plant for the extraction of both uranium and thorium from monazite is in operation at Alwaye in Travancore-Cochin State and a second plant at Trombay, near Bombay, will be in operation by May 1955.

Similarly, the Indian Government is advancing the production of heavy water at Bagkra Nangal where large amounts of cheap power are available and where five to six tons of heavy water can be produced per year as a by-product for the production of 250,000 tons of fertilizer. The construction of an atomic reactor lies in the future after the preliminary stages of the production of uranium, thorium and heavy water. Nevertheless, India plans to have her first atomic reactor in operation by 1958 and adequate funds have been made available by the Government to the Indian Atomic Energy Commission.

India looks ahead

On November 26 and 27, a two-day Conference on the Development of Atomic Energy for Peaceful Purposes in India was held at New Delhi, and attended by Prime Minister Nehru, Dr. H.J. Bhabha and some hundred scientists. Closing the Conference, the Prime Minister stated that India has a formal agreement with France which has yielded good results in that young Indians are being trained in France for work on atomic energy development in India. There is also a limited agreement with the U.S. and informal agreements with Norway and Sweden.

"It is beginning to be realized by people all over", said the Prime Minister, "that something rather basic in human experience has been happening in connexion with all that has gone on in recent years in regard to the development of atomic energy. It is something which gives you some glimpses... into all kinds of secret forces of nature. But this tremendous power suddenly opened out for human use... can be used for good or evil... it therefore becomes necessary for us to try to understand it, to try to train our people in it, and try not to lag behind in this process."

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'UNDER WAY ON NUCLEAR POWER'

The use of nuclear power for the propulsion of ocean-going vessels became a reality recently when a U.S. atom-powered submarine, the Nautilus, began its sea trials and its captain signalled: 'Under way on nuclear power.' Costs must be reduced, however, before this form of propulsion can become commercially practical. Photos on this page show some aspects of the development of atomic marine engines in the United States. (1) The prototype of the reactor which drives the Nautilus being tested in its land-based hull at a testing station in the Idaho desert. Reactor was generating power when this photo was taken. (2) The same power-plant seen through the door of the testing station. (3) The Nautilus being fitted out in a shipyard. (4) The 225-feet high sphere at West Milton, New York in which tests are made of a land-based prototype of a second nuclear submarine, the Sea Wolf.

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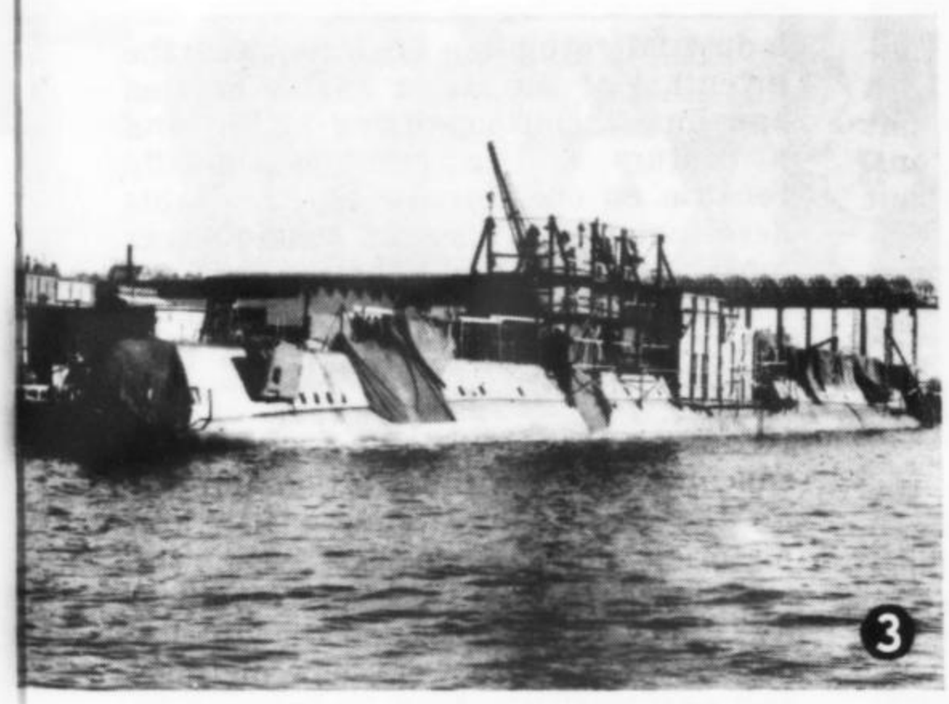
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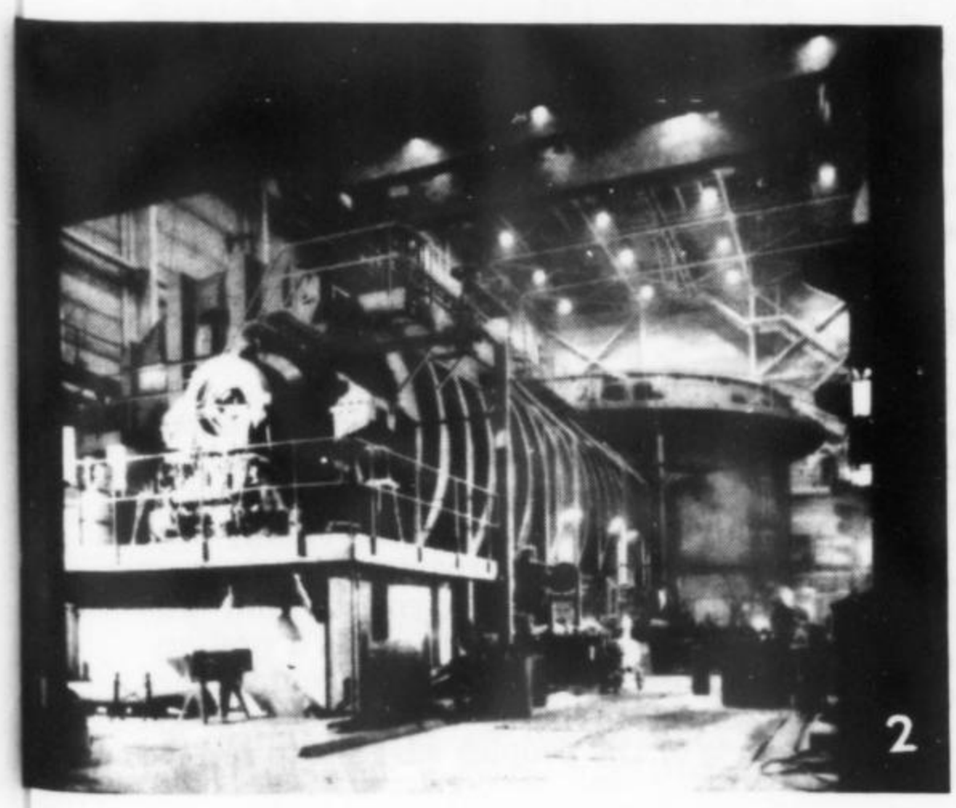
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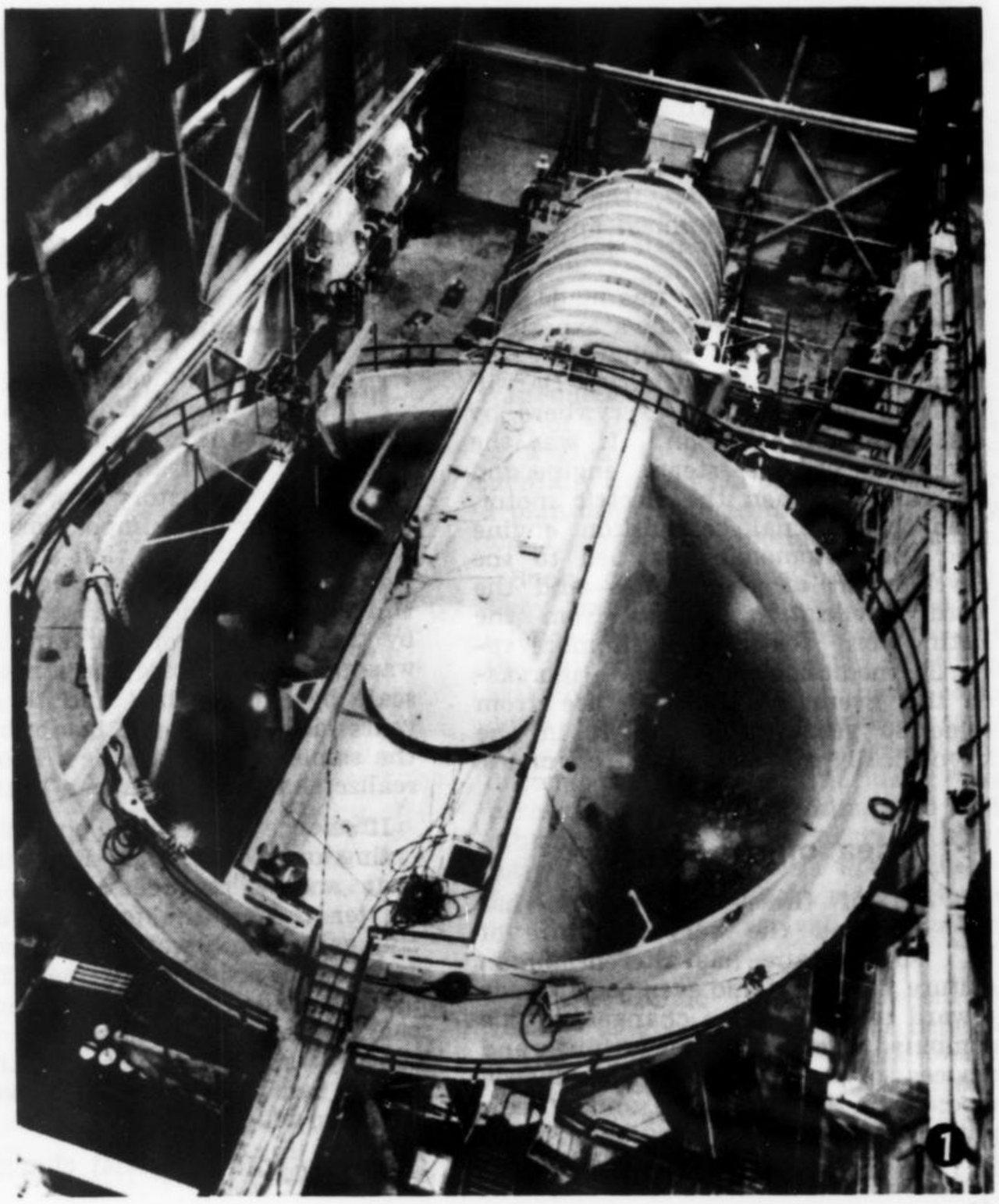
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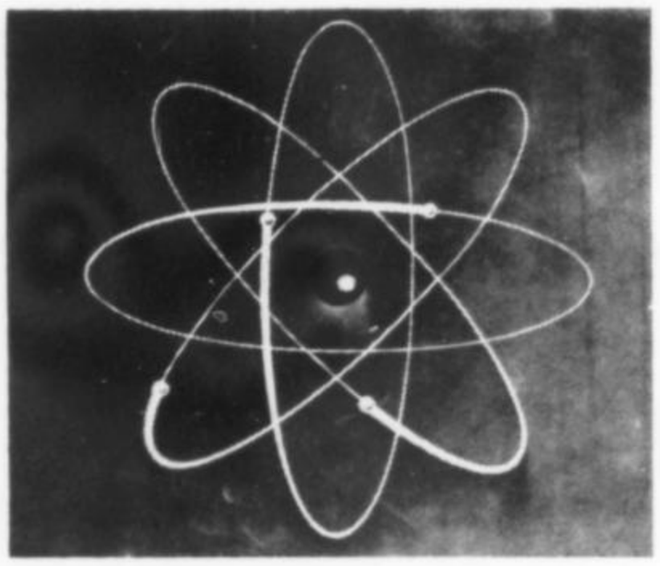


We must learn to live with the atom today...

...TOMORROW WILL BE TOO LATE

THE atomic bomb erupted unannounced in August of 1945 from behind an impenetrable wall of military secrecy. The world was totally unprepared. Since then every nation has been revising its military and political plans to adjust to the global consequences of that explosion. The peaceful uses of the power of the atom have been slower in coming and their consequences will also be less sudden. Yet in the perspective of history the effects will be both large and relatively rapid.

The new products of science and its major ideas have always in the past had far-reaching influence on man's way of life and on the social structure, particularly during the rapid progress of the past century. Ages ago it was the invention of the smelting of bronze and iron from their minerals, or it was the proof that the earth is a sphere, or the invention of gunpowder, that led to large political, geographical and social readjustments.

The era of machines was made possible by Sir Isaac Newton's exposition of the principles of mechanics. Less than a century ago Charles Darwin changed human ideas everywhere by his theory of evolution. It was the invention of the steam engine and the railroad, then the electric motor, then the internal combustion engine and the automobile that led to the development of great cities—and the word "civilization" comes from the Latin word for city. Still more recently, medical advances have increased the average length of life from some 30 years to almost 70 in the scientifically more advanced countries.

Idea of the century

EACH of these developments has changed the very structure of society, and has altered human culture, education and even the attitude toward religion. Such changes are the combined effect of the new things and devices, of new practices in industry, medicine and agriculture, and of new philosophical ideas. Together they are the most powerful of all the forces that continually change life and society, and speed social evolution.

In this century the basic new idea is Einstein's theory of relativity. This has as yet hardly begun to influence popular thinking. But its greatest consequence today is the fact that, as Einstein predicted, matter and energy are not two separate, immutable components of the universe but that they can by proper means be changed one into the other.

This is probably the most revolutionary idea that has come from the mind of man in all the centuries. It was a mathematical theory, generally disregarded, until Otto Hahn and F. Strassmann in Germany in 1939, conducting esoteric experiments with single atoms of uranium, showed that these atoms, when struck by neutrons, explode with the annihilation of about 1 % of their matter and the corresponding generation of an almost incredible energy.

Fear—and its antidote

THAT was the year in which the second great World War began so that the experiment was almost unnoticed by a frantic world. Yet in the records of history it will probably appear as far more important than the war itself. It proved that Einstein was right. Only three years later at the University of Chicago a group headed by the Italian Professor Enrico Fermi was generating energy on a respectable scale by this method and three more years later the atomic bomb, based on the same principle, made all the world realize that a new era had begun.

If science is the most powerful force acting on society, then Einstein's idea that energy can be created out of matter is now the primary force for change in man's way of life and in his attitude toward the universe. This will become evident during the next fifty years, perhaps by the end of the century—and that means within the period when our present youth and children will inherit the earth.

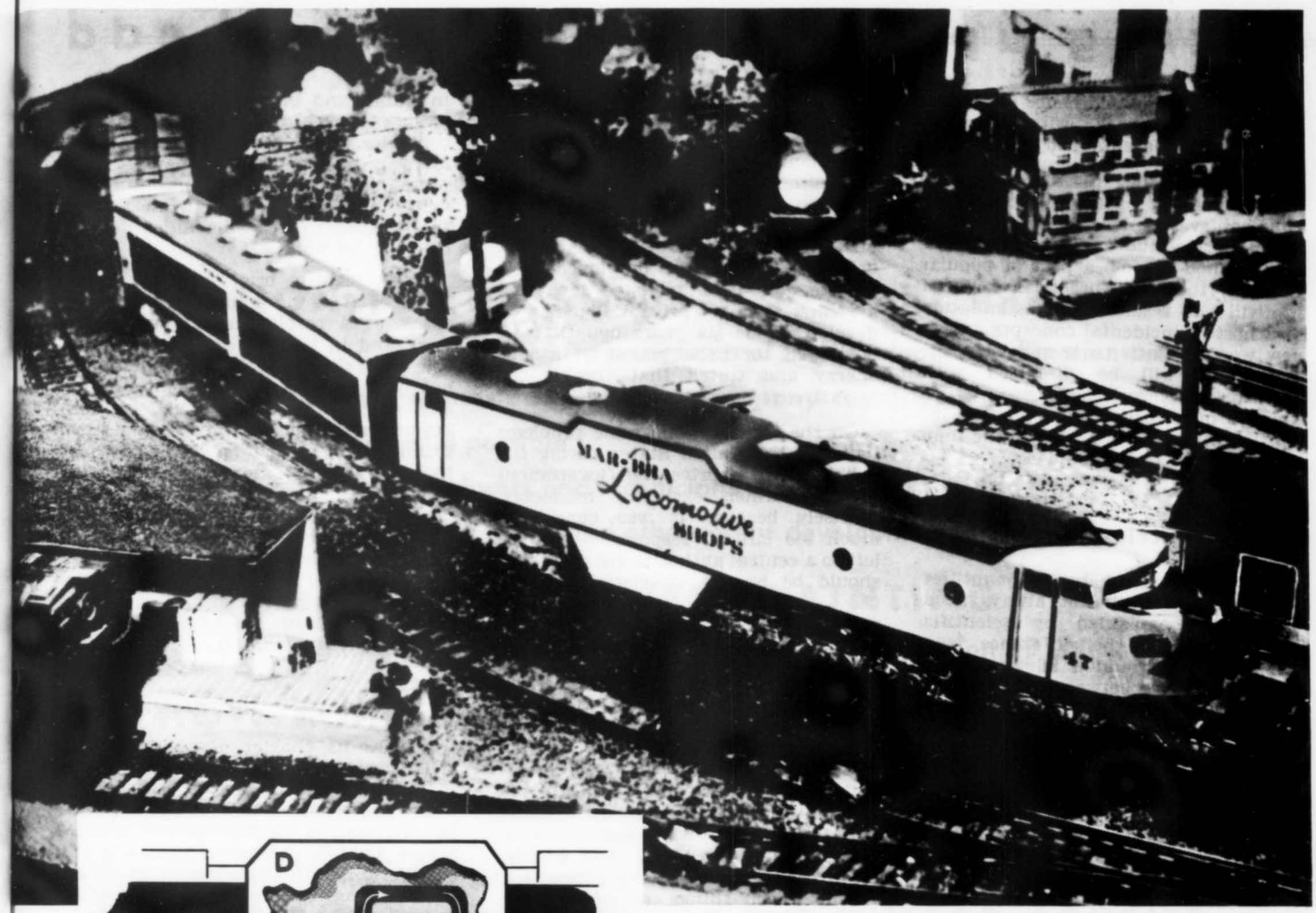
Science enforces social change. Yet to the human mind change is seldom welcome. It is opposed because it is feared and feared because it is not understood. The fear of the atomic bomb is universal and hysterical. The fear of the beneficent atom will develop later when its consequent social changes become evident. Governments may decree that such changes are desirable and will result in improved living for more people. So they will, probably But if means are not taken in advance to safeguard the individual persons who will be displaced or whose lives will be changed, evil results will accompany the good.

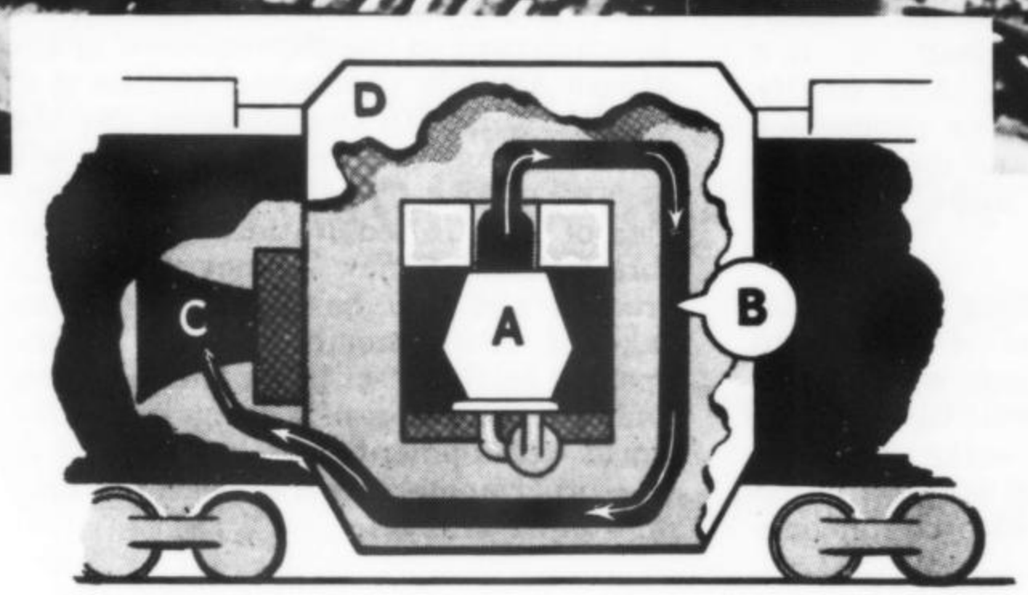
It cannot be forgotten that the industrial revolution that followed the invention of the steam engine created appalling social conditions in England a century and a half ago, chiefly because no one foresaw the inevitable developments. This time consequences must be foreseen. Above all, the element of fear must be reduced or eliminated.

Since fear is usually fear of the unknown, the preventative of fear is education. The United Nations project for the wide use of atomic energy and materials must consider well the experience in the work of Technical Assistance to underdeveloped countries, namely that new powers, new methods and new wealth cannot be imposed by the donation of machines and facilities, however precious, unless they are understood and are welcomed by a people that understands them and wants both them and their consequences.

Science-conscious world

THE atomic power project is therefore not merely a matter of placing great nuclear reactors in countries that need more energy and more wealth. It requires not merely the education of scientists and engineers. Even more it needs a preliminary programme that may require years but must prepare the minds and the hearts of the peoples who are to receive





ATOMIC-POWERED LOCOMOTIVE shown here only exists today in Lilliputian form as a model designed at the University of Utah, U.S.A., anticipating the day when railroads will make practical use of nuclear energy for power. Cutaway section (left) illustrates basic principles of the engine. Nuclear reactor (A) containing a solution of uranium 235 would produce steam which would pass through pipes (B) to steam turbine (C). Turbine would drive four generators producing electricity to drive the locomotive. A 500,000 pound steel block four feet thick (D) would protect the train crew from radiation

its benefits for the changes that are to come.

Such education of the public, and particularly of the adult public, in turn means much more than explaining atomic energy. In a sense it will, in many lands, require what amounts to a cultural revolution.

It will involve first the adoption of the scientific attitude of mind which is in its essence one of welcoming a problem to be solved—whether it be a problem in mathematics, mechanics or science, whether it be a problem in economics, world trade or in relations between social classes or between nations. In an unscientific culture a problem of whatever sort is often the occasion for despair, for violence or for prayer. Then a problem is a thing to be avoided because the answer seldom comes with it.

But the scientific mind thrives on problems, analyses them, attempts one solution after another until the answer is found, usually on the basis of past experience or general principles. In science most problems eventually—though sometimes only after extended and patient effort—find a satisfactory answer. Thus scientists typically welcome a problem as a challenge to their intelligence, as an inspiration to their best thought. Such an attitude will certainly be needed in the face of the enormous possibilities that are inherent in the atomic project.

Try it and see

SECONDLY, an economy based on atomic energy must certainly adopt what is often called the scientific method but which is in fact the simple method of experiment. Its first impulse is to "try it and see", if possible on a small scale, in order to test whether the idea, explanation or project is correct or feasible. In the dawn of the atomic age there will be numberless concepts and plans in engineering, public works, legal measures and social readjustments, whose consequences cannot be foreseen for lack of experience. It will be the part of wisdom to test such ideas experimentally and to adopt a conclusion or a plan after such tests and not hastily under pressure of emotion or prejudice.

Such considerations are cultural. They imply not the substitution of science for an unscientific culture but the integration of scientific attitudes with cultural ideas that have come down through the centuries, largely untouched by science. In many industrial countries scientific ideas have perhaps been all too dominant so that ethical principles and spiritual ideas have faded. A synthesis would therefore be desirable on both sides. If this is so, a profound revival of values is everywhere desirable.

If the atomic age is to be one of plenty, of good living and of benefits both broad and deep in all nations, it must be accompanied by a revision of education in all countries, both advanced and underdeveloped, which must start in the primary schools—in-

Facing up to the problems ahead

deed in the home and hence must start even further back with the re-education of parents and teachers.

If, under the incentive of the development of atomic power science thus achieves a place in older cultures and the scientific attitude and scientific method become a part of popular thought, then the practical facts of life will also result in the assimilation of a host of incidental concepts and of new words. Matter and energy, space and time, will be discussed with precision, in poetry and in prose. The concept of velocity, as a change of position in space in relation to the time elapsed, will be commonplace.

From proteins to genetics

THE difference between quantities and rates will not always need to be explained by scientific writers—such as the difference between a kilowatt and a kilowatt hour or the difference between calories and horse-power. Such simple words from the world of science will be commonly understood when energy and power are everywhere supplied to remote farms by transmission lines from the atomic reactors. Common also will be the understanding of what electricity is, and electrons, solutions, proteins, vitamins and hormones. The principles of heredity and genetics will be understood to the great benefit of race relations.

Large principles, such as evolution, celestial mechanics, the nature of the planets and the origin of the earth, will all merely be background for human studies, not academic specialities limited to the erudite. Such topics will be part of the curriculum of the primary schools and it is in learning the facts and the logic on which they are based that children and adults will learn the methods and mode of thought of science.

Job for the State?

IF this seems visionary it is because the time is still far off. Yet it must come if the human race is democratically to solve such problems as the atomic age will certainly bring—problems such as how to grow enough food to support the workers that the atomic industries will require; how to provide water to the arid zones so that the population can thrive and use the electric power that can easily be brought there; how to provide medical care to large populations that atomic energy will make possible; how to distribute the wealth that great atomic industries will create and that automatic factories, perhaps, will convert into tangible goods; how and by what steps it will be possible to increase the standard of living.

These are problems that each nation must solve for itself. There will be diverse answers. An example is in the statement of Prime Minister Nehru of India who said, in opening the Conference on the Development of Atomic Energy for Peaceful Purposes in India, on November 26: "No State can allow atomic energy to be developed in a private way—it is much too dangerous a thing for a private agency to develop... it is six years ago that we envisaged the development of atomic energy and stated that this is the exclusive responsibility of the State."

On the contrary, the same problems have led the United States during the past year to deprive the Government of its former exclusive monopoly, precisely because it was considered much too large a responsibility to be left to a central authoritative group but should be broadly developed through the various venturesome ideas of private groups.

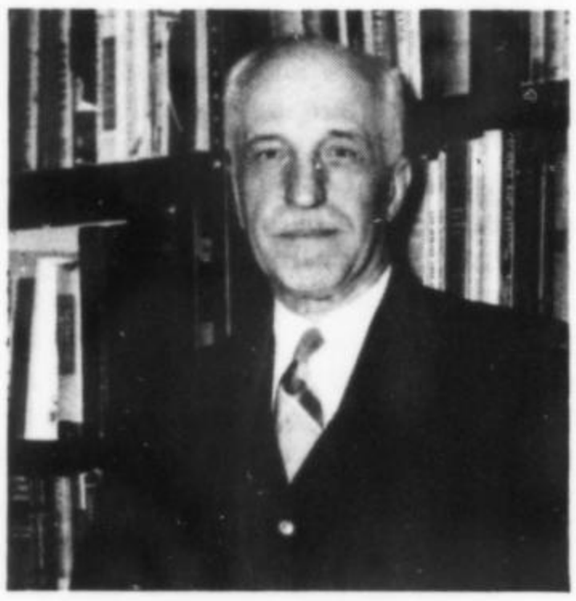
There are even larger questions that will arise. As countries profit from ample energy and thus increase their productivity and reduce the cost of their goods, there will be increased competition in the international markets and radical readjustments in international trade. These, in turn, will lead to new tensions between States. And finally, in all countries increased production will mean more things and more money but it will also mean more free time for the workers.

In the hard-working industrial countries this payment of profits in time rather than in money will present a major problem. It will, however, be an unequalled opportunity for the development of a true culture based on the assurance of an adequate income in things and in money—plus time to enjoy them. In the non-industrial countries, where leisure has often been more prevalent than money, it will present a problem of maintaining the values of a leisurely life while letting the engines and the machines do the bulk of the work.

After such a brief review of the prospect it is no longer startling to speak of a revolution in the world's work and in its way of life. Perhaps the term should be "rapid evolution", not quite so fast as a revolution. In any case, one's vision must go far beyond mere nuclear physics and the technology of reactors. It is obvious that the coming atomic age requires foresight not merely from physicists and engineers but also from educators, social scientists and exponents of culture. It requires not only foresight but planning and action, lest the revolution overwhelm us. This great development must be guided for the benefit of mankind.

World plan for progress

UNDER its charter, UNESCO faces a new challenge long before it has solved the problems of the present. Every department of UNESCO will be concerned in the development of the atomic age and the special functions of the World Health Organization and the Food and Agriculture Organization will also be needed. The Specialized Agencies of the United Nations will therefore welcome a new Agency when it is created and will be prepared for the sake of their member states to co-operate in the discussion, the planning and the operation of a programme for world development that is inherent in the programme for the peaceful uses of atomic energy.



GERALD WENDT

The series of articles on atomic energy in this issue of the *Unesco Courier* was written by Dr. Gerald Wendt, Head of the Division of Teaching and Dissemination in Unesco's Department of Natural Sciences. He is the author of *The Atomic Age Opens* and of *Atomic Energy and the Hydrogen Bomb*. Formerly a professor of chemistry at the University of Chicago and Dean at the Pennsylvania State College, he has devoted recent years to the interpretation of science and its social consequences in public lectures, on the radio and by television. He has been Director of Education at the World's Fair in New York, Science Editor of the American weekly, *Time*, and Editorial Director of the monthly, *Science Illustrated*. At Unesco he organized *Impact* as a quarterly journal on the effects of science on society and is editor of *Unesco Science News*. His articles on science in the *Unesco Courier* and in *Unesco Features* have been translated into many languages and reprinted in the newspapers and magazines of a large number of countries.

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SAFETY SUIT of the type worn by atomic energy plant workers doing certain jobs where there is danger of exposure to high degrees of radio-active contamination. Mask prevents the inhalation of gas or radio-active dust. Constant vigilance is exercised and, in fact, workers in atomic energy plants are in far less danger of injury from radiation than are other workers from the ordinary hazards of industrial life—burns and scalds, cuts and bruises. Leakproof suit shown here is entered by the worker from an adjoining room through a plastic tunnel which culminates in the suit itself. It is part of an exhibit on the Peaceful Uses of Atomic Energy held recently at U.N. Headquarters, New York, and is being examined here by Mrs. Lakshmi Menon, a representative of India to the General Assembly. (U.N. Photo).